

SCIENTIFIC REPORTS

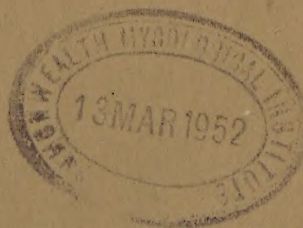
OF THE

Indian Agricultural Research Institute New Delhi

For the year ended 30th June, 1949



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an Agricultural Chemist under the Imperial Department of Agriculture was proposed in 1882, and the proposal was repeated in 1884 and 1886: but the appointment was made only in December 1889 as a result of a very strong representation of the Agricultural Conference held in Delhi in 1888. To this post Dr. J. A. Vœlcker, Consulting Chemist to the Royal Agricultural Society of England was appointed. This marked the beginning of a systematic scientific enquiry in agriculture in India. Dr. Vœlcker left India early in 1891. His impressions and recommendations are contained in his "Report on the Improvement of Indian Agriculture", 1893. For the purposes of agricultural enquiry on scientific lines, Dr. Vœlcker recommended that an Agricultural Chemist, an Assistant Chemist, a Botanist, an Entomologist and an Agricultural Engineer should be appointed by the Government of India. In October, 1890, at an Agricultural Conference held at Simla, a preliminary note prepared by Dr. Vœlcker was considered and the Conference advised the Government that a really competent man should be appointed as an Agricultural Chemist and he should have the help of an Assistant Chemist. The appointment of Dr. J. W. Leather and of Mr. S. H. Collins respectively to these posts in 1892 was the beginning of the scientific staff of the Imperial Department of Agriculture.

The next step followed the Report of the Famine Commission of 1901 which found that "the steady application to agricultural problems of expert research is the crying necessity of the time"¹ and recommended the strengthening of expert staff. As a result the scientific staff of the Imperial Department of Agriculture was further strengthened by the appointment in 1901 of the late Sir Edwin J. Butler as Imperial Cryptogamic Botanist (later designated Imperial Mycologist), and in 1903 of the late Mr. Maxwell Lefroy as Imperial Entomologist. They, however, worked at different places.

The Institute at Pusa

The recommendations of the Famine Commission were further implemented after the approval of the Secretary of State for India had been obtained of the scheme which was submitted by Lord Curzon with his despatch dated the 4th June, 1903. The scheme as sanctioned by the Secretary of State was the establishment of—

- (1) An Experimental Farm
- (2) An Economic Botanical Garden
- (3) A Research Institute
- (4) An Agricultural College
- (5) A Cattle Breeding Farm

The chief functions of the farm would be to afford a training ground for the students of the college, a means to the scientific experts of working out on a practical scale the many problems which await their investigations, and a distributing centre for improved seeds and plants. The Economic Botanical Gardens in charge of the Economic Botanist would be for the use of the scientific officers and the students, and would contain as far as possible a complete collection of the economic plants of India. The Research Institute would have spacious laboratories fitted with the best apparatus for scientific research, and would also contain a library of the most important works and

¹ Royal Commission on Agriculture in India—Report, p. 20.

periodicals allied to agriculture as well as a museum and a herbarium. The publication of the work done at Pusa under the control of an Editorial Committee of the staff was to be one of the most important undertakings of the institute, and it was intended that a central bureau of reliable information on agricultural subjects should thus be created for the whole of India. The College for the training of students would be attached to the institute. It was to be of the University type, for post-graduates, and would be fed by the agricultural colleges of the Provinces. In the latter, students would undergo a course of three years' training in general scientific and practical work, and the most successful candidates would pass out of the provincial college into Pusa, there to complete another two years of specialised training. By this method it was expected that it would be possible to supply for the agricultural departments in India scientific men of a high order, who, it was hoped, would be competent to fill the highest posts in professorial work, or become reliable specialists for original research work, and thus supply one of the greatest needs of the country. The Agricultural Research Institute and College (later renamed successively the Imperial Institute of Agricultural Research, the Imperial Agricultural Research Institute, and the Indian Agricultural Research Institute) was thus established by the Government of India in 1905 at Pusa. The laboratories of the Institute at Pusa bore the name of Mr. Henry Phipps, an American philanthropist, whose generous donation of £30,000 enabled the establishment of the Institute. The laboratories of the Division of Agricultural Chemistry and Soil Science at Delhi now bear his name.

With its establishment in 1905 the posts of Agricultural Chemist, Mycologist, and Entomologist were absorbed in the Institute. "To them in 1904 were added a Director of the Institute, and in 1905 an Agri-Horticulturist (subsequently designated Imperial Agriculturist), a Biological Botanist (subsequently designated Imperial Economic Botanist)".¹

A research station with laboratories and an experimental farm, a cattle breeding farm for the improvement of local breeds of cattle formed the Institute but an agricultural college for the training of students which was intended to be a part of it was not established. The educational activities of the Institute were restricted to higher courses of training of the staff of the provincial departments of Agriculture, who desired "to qualify for professorship, research work, or posts requiring special scientific attainments."² Post-graduate courses of two years' duration were instituted at Pusa in 1923 but no syllabi of studies were laid down and no regular courses of instruction in the form of lectures, practical work, field investigations etc. given, nor were there regular examinations of the candidates during and at the end of the course, until November, 1945.

The Institute at Pusa started with the five divisions called sections :

1. Agriculture and Cattle Breeding
2. Chemistry
3. Economic Botany
4. Entomology; and
5. Mycology.

^{1,2} Royal Commission on Agriculture in India—Report, p. 30.

To these was added a cotton breeding section in 1907 under the late Mr. G. A. Gammie as Imperial Cotton Specialist but was closed down in 1919 with his retirement. This work was taken over by the Indian Central Cotton Committee in 1921, but the Agricultural Adviser and Director of the Institute continued to be the President of the Committee till 1929. During 1909-10 two sections of Bacteriology and Pathological Entomology were started but the former was absorbed in the Chemistry Section in 1934 and the latter in the Entomology Section in 1921. It was in the Pathological Entomology Section of the Institute that the work on Veterinary and Medical Entomology was started in India. In 1916 the Indigo Research Section was created for a period of five years to investigate the possibility of resuscitating the declining indigo industry of Bengal and Bihar in the face of competition of the German synthetic dyestuff industry. In 1921 on the termination of the period, the Section was closed down. The results of its researches are available in a series of publications of the Institute known as the "Indigo Publications." In 1919 another section known as the Protozoology Section to investigate the Pebrine disease of silk worms was created for a period of two years. This Section was closed down in 1921 and the results of research were published in a memoir entitled "Pebrine in India" by C. M. Hutchinson (1920). A sugar Bureau for the collection of all available information in connection with the sugar industry in India was also created in 1919 in the Institute but with the establishment of the Indian Institute of Sugar Technology under the Imperial (now Indian) Council of Agricultural Research in 1930 the Bureau was transferred to Kanpur. In 1920 there was yet another section of the Institute created *viz.* that of the Imperial Dairy Expert with headquarters at Bangalore. A section of Physiological Chemistry dealing with animal nutrition problems was added in 1921 at Pusa and in 1923 on the recommendation of the Inchlape Committee (1922) was transferred to Bangalore to work in conjunction with the Imperial Dairy Expert. The same Committee also recommended the transfer of the Military Dairy Farms at Bangalore, Karnal, and Wellington and the Creamery at Anand to be transferred to the Institute under the Imperial Dairy Expert and this recommendation was given effect to in 1923. In the same year was established the Imperial (now Indian) Institute of Animal Husbandry and Dairying at Bangalore as a unit attached to the Institute at Pusa under the immediate charge of the Imperial Dairy Expert. The Institute of Animal Husbandry and Dairying was, however, placed in direct relation with the Government of India in 1936 and the Imperial Dairy Expert was subsequently made the Director of Dairy Research. The Indian Dairy Research Institute is now a separate organization and has got a permanent Director. In the same year, however, Karnal (1936) was taken over by the Indian Agricultural Research Institute and made a substation of its Agricultural Division. The Sugarcane substation at Coimbatore maintained by the Madras Government with a subsidy from the Central Government was taken over by the latter and placed under the Director of the Indian Agricultural Research Institute in 1925. Just as in the case of cotton, veterinary and medical entomology, animal nutrition and dairying, the foundation of research in silk, lac, bee-keeping, tobacco, and potato in India was laid by the Indian Agricultural Research Institute which nursed the research activities in these subjects till they were taken over respectively by the Bhagalpur Silk Institute, the Indian Lac Research Institute at Ranchi, the Tobacco Research Institute at Rajahmundry under the Indian Central Tobacco Committee, and the Central Potato Research Institute at Patna. Experiments with fruits in Baluchistan were also conducted by the Institute in its earlier stages of development. The results have been published in the Quetta Fruit Station Bulletins.

In 1911 the post of Inspector-General of Agriculture created in 1901 was abolished and the Director of Agricultural Research Institute was also assigned the duties of the Agricultural Adviser to the Government of India. The Veterinary Research Institute at Mukteswar was simultaneously placed under the control of the Director and Agricultural Adviser. On the recommendation of the Royal Commission on Agriculture in India,¹ the Mukteswar Institute was placed in direct relation with the Government of India in 1929 and later the work on animal nutrition was transferred from Bangalore to the Izatnagar branch of the Mukteswar Institute.

As stated earlier the Agricultural Adviser combined with his duties those of the Director of the Agricultural Research Institute and was also the President of the Indian Central Cotton Committee. This arrangement continued until 1929, when the functions of the Agricultural Adviser were transferred to the Vice-Chairman of the Imperial Council of Agricultural Research, which was established as a registered society. The Royal Commission on Agriculture recommended that the post of Director should be whole-time one and this recommendation was accepted by the Government of India. Dr. B. A. Keen of the Rothamsted Experimental Station was recruited in 1930 as a whole-time Director for one year. In consequence of certain retrenchment proposals it was decided that the Director should take an active part in research and that his duties should be combined with those of Head of a Division. And from November, 1931 the combined post had been so held until October, 1945, when the present Director was invited by the Government of India to take up the appointment on a whole-time basis.

Prior to 1905 the then Imperial Department of Agriculture in India used to publish scientific papers in the Series known as the *Agricultural Ledger*; but with the establishment of the Institute at Pusa, a Publication Section was formed under the Agricultural Adviser and Director of the Institute. *Agricultural Journal of India* (a monthly); *Bulletins of the Agricultural Research Institute*; *Memoirs of the Imperial Department of Agriculture in India*; *Catalogue of Indian Insect*; *Review of Agricultural operations in India* (Annual); and the *Scientific Reports of the Institute* used to be published. But with the establishment of the Imperial Council of Agricultural Research the publication work was taken over by the Council in 1930 except that the *Scientific Reports* are still being issued by the Institute. More than 2,000 scientific papers including monographs and memoirs have so far been published by the staff of the Institute.

Some of the most important books dealing with agricultural subjects have been published by the members of the staff of the Institute as the following list will show:—

1. Lefroy, H. M.—Indian Insect Pests. Calcutta, 1906 (Superintendent of Government Printing, India, Calcutta);
2. Lefroy, H. M. & Howlett, F. M.—Indian Insect Life—A manual of the insects of the plains (Tropical India). Parts I-II Calcutta, 1909 (Thacker, Spink and Co., Calcutta);
3. Howard, Albert and Howard, G. L. C.—Wheat in India—Its production, varieties and improvement, Calcutta, 1909. (Thacker, Spink & Co., Calcutta);
4. Mackenna, James—Agriculture in India. Calcutta, 1915 (Superintendent, Government Printing, Calcutta);

¹ Royal Commission on Agriculture in India—Reports, p. 318.

5. Hutchinson, C.M.—The Importance of Bacterial Action in Indigo Manufacture. Calcutta, 1917 (Thacker, Spink & Co., Calcutta);
6. Butler, E.J.—Fungi and Disease in Plants. Calcutta, 1918 (Thacker, Spink & Co., Calcutta);
7. Jameson, A.P.—Report on the Diseases of Silkworms in India. Calcutta, 1922. (Superintendent, Government Printing, India, (Calcutta) ;
8. Howard, Albert—Crop Production in India—A critical survey of its problems. London. 1924 (Oxford University Press, London);
9. Fletcher, T.B. & Inglis, C.M.—Birds of an Indian Garden. Calcutta, 1924. 2nd Ed. (Revised & Enlarged), 1936 (Thacker, Spink & Co., Calcutta);
10. Mundkur, B.B.—Fungi and Plant Disease. London, 1949 (Macmillan & Co., London).

Contact with the Provinces

The Royal Commission on Agriculture in reviewing the position of Pusa in relation to the province observed that there was "a lack of touch between Pusa and the Provinces and between province and province."¹ They attributed this in part to the independence of the provinces in regard to agricultural research and education and in part to "the fact that the spheres of provincial and central research have never been clearly defined."¹ They further remarked "it is unfortunate—that Pusa was not, from the outset, an educational as well as a research institute"¹ as they considered that "a constant stream of men returning from Pusa to the provinces would have furnished an excellent means of maintaining contact between"¹ it and the provinces. With the reorganization of the post-graduate training of the Institute, the collaborative investigations undertaken during the past few years and a larger number of admissions of youngmen from the provinces it is expected that a better contact will be maintained between the Institute and the provinces.

On the creation of the Indian Council of Agricultural Research the coordination of agricultural research in India became one of its functions. The various Commodity Committees, such as the Indian Central Sugarcane Committee, the Indian Central Jute Committee, and others, have their separate research and administrative establishment; the only link between them consists in the Vice-Chairman of the Indian Council of Agricultural Research being the ex-officio President of all of them. It has, however, been recognized that the Indian Agricultural Research Institute is primarily meant for fundamental research in agriculture and for advanced training in the agricultural sciences. Apart from there being no suitable organization for bringing about an effectively close collaboration between the Institute and the provincial research station, the "sectional" meetings which used to be held previously at Pusa have been abandoned. The scientific committees of the Indian Council of Agricultural Research and of the Commodity Committees provide, however, to a limited extent a meeting ground for a number of workers in the agricultural sciences in the country. Tours to provinces by the scientific staff of the Institute also provided some opportunity, although rather limited, for contact with the provinces. There is also no relationship direct or indirect between the Institute and the agricultural activities of the centrally adminis-

¹ Royal Commission on Agriculture in India—Report, p. 46.

tered areas. Nevertheless, the Institute has been playing its part in developing closer collaboration with and in giving assistance to the provinces and Central establishments in various ways. The extent of such collaboration depends on the demand from the departments of agriculture of the provinces and state unions and from the Commodity Committees. The Institute helps in the identification of insect pests of field crops and of fungi responsible for plant diseases; supplies named specimens of insects, of fungi and other micro-organisms and their cultures; promotes the introduction of economic plants in different parts of India either for direct trials or for purposes of evolving new plant material from its collections, which have been greatly enriched since 1946; supplies coloured plates of insect etc. for educational institutions; analyses soils and plant material for specific purposes on request from provinces and state unions which have not got the necessary facilities; carries out soil surveys as desired by the Ministry of Agriculture for state unions, or by Commodity Committees, or by the Indian Council of Agricultural Research. It supplies seeds of better varieties of plants evolved in the Institute for trial in the provinces and state unions and also foundation stocks of such varieties as are in demand in any one of them. The Institute also advises the Government of India and provinces when desired by them on various aspects of agriculture. A regular feature of the help rendered by the Institute to the agricultural scientific workers throughout the country is the supply of literature and information from the Institute library which is the best of its kind in India. A photostat has recently been fitted up with a view to supply photo-copies of scientific articles which may be required by individual agricultural research workers. The number of well-equipped libraries in the agricultural sciences is quite small. By far the majority of men engaged in agricultural research have very little library facilities and are not in a position to keep in touch with the recent developments in their subjects. With a view to develop the Library Information Service, Government have sanctioned a post of Technical Information Officer; the appointment has, however, not yet been made.

Reorganization of the Institute

The Royal Commission on the Superior Civil Services in India (1924) recommended the cessation of recruitment from abroad to the all-India Agricultural Service and emphasised the necessity of providing facilities for higher training in agriculture in India and that India should "become self-contained in the matter of agricultural training at an early date so that it may not be necessary to send Indian students abroad for this purpose"¹. According to the Royal Commission on Agriculture, "the view which was taken at the outset was that an agricultural college was required at Pusa not only to provide for the needs of Bengal which had no college of its own but also to serve as a model for, and to raise the standard of, agricultural colleges in other provinces and to provide for a more complete and efficient agricultural education than was then possible in any of the existing institutions. The aim was thus two fold. In the first place, it was intended to train students who were not in a position to be admitted to any of the provincial colleges and schools. In the second place, it was intended to provide for a higher course of training for those who had studied at provincial institutions and who desired to qualify for professorships, research work or posts requiring special scientific attainments. As regards its educational activities, owing to the establishment of

¹ Royal Commission on Agriculture in India—Report. p. 36.

fully equipped agricultural colleges in the provinces, Pusa was never called upon to provide for the first of the groups of students mentioned above for which it was originally intended. In respect of higher agricultural education, the weight attached in recruiting for the Indian Agricultural Service to the possession of degrees in honours in science of British Universities or of diplomas from recognized schools of agriculture in Great Britain and the superior facilities for post-graduate work which were regarded as available at those universities and schools meant that Pusa had nothing to offer which the advanced student did not, as a rule, prefer to obtain elsewhere¹. Until the end of 1923, its teaching activities were confined to short courses in special subjects. In November of that year with a view to enabling candidates for the higher ranks of the agricultural services to qualify for them in India, post-graduate courses of two years' duration were instituted at Pusa. The Commission recommended that "Pusa should be developed as a first class centre for advanced training and research in agriculture"². The Government of India sought the advice of the Indian (formerly Imperial) Council of Agricultural Research; and the Advisory Board of the Council in January 1931 recommended that "Pusa should continue to be developed actively and to the greatest possible extent as an Institute of fundamental research. If facilities for post-graduate training analogous to those provided at present are then offered it will attract research students in proportion to its success as a research centre."³ The Government of India noted in a resolution in 1931 that "the question of providing increased facilities for higher agricultural education at the Imperial Agricultural Research Institute, New Delhi, is under consideration for sometime, but no action could be taken owing to financial stringency."⁴

The Policy Committee on Agriculture, Forestry and Fisheries recommended at their meeting in June 1944 that the facilities for training in agriculture and animal husbandry available at the Institute should be further expanded and special attention paid to the training of extension staff for the departments of agriculture in the provinces. At the instance of the Government of India and as a preliminary to the extension of facilities in training and research in the Institute, the Indian Council of Agricultural Research convened in July 1945 a meeting of Directors of Provincial and State Departments of Agriculture and of a number of eminent scientists for advising what additional post-graduate courses of training in the different branches of agricultural sciences should be provided for. The Committee recommended that the existing courses should be reorganized to provide for advanced post-graduate training having a duration of two years. They recommended that these two years' courses should cover the following subjects:

1. Agriculture
2. Genetics & Plant Breeding
3. Cytology
4. Physiology
5. Economic Botany

¹ Royal Commission on Agriculture in India—Report. p. 30.

² Royal Commission on Agriculture in India—Report, p. 67. Recommendation No. 22.

³ Sixth Report showing the progress made in giving effect to the recommendations of the Royal Commission on Agriculture in India upto the end of 1937. p. 4.

⁴.....*Ibid*..... p. 5.

6. Soil Science & Agricultural Chemistry
7. Soil Science
8. Agricultural Chemistry
9. Soil Microbiology
10. Entomology
11. Toxicology
12. Ecology
13. Other advance aspects of Entomology
14. Mycology & Plant Pathology
15. Virus
16. Agricultural Engineering
17. Agricultural Economics, and
18. Sugarcane Breeding.

The Government of India accepted this recommendation. A plan for reorganising the Institute so as to develop it to the fullest possible extent as an Institute of fundamental research and higher training in agriculture providing for the above courses of advanced training was submitted to the Government of India in October, 1945. The Department of Education, Health and Lands of the Government of India with the concurrence of the Department of Planning and Development and the Department of Finance accepted the plan of reorganisation and gave effect to it. The replies from the Departments of Agriculture and States showed that the number of admission to the post-graduate courses which could be expected annually was about 85.

The Institute at New Delhi

After the great earthquake of 1934 in North Bihar, the Institute was transferred to New Delhi. The Institute—popularly known as Pusa Institute—is situated about five miles west of New Delhi railway station on an estate originally consisting of about 850 acres of land, of which the area under crops comprises approximately 400 acres. In 1946, 104 acres of *Nazul* land were acquired on the southern side of the Institute and in 1949 a further area of 137 acres of *Nazul* land contiguous to the former was handed over to the Institute. This new area is to be used as sites for urgently required buildings and for experimental studies. At the suggestion of the Hon'ble Minister Shri Jairamdas Daulatram, 60 acres out of this land have been set apart for farming by the nearby villagers under the advice of the Institute.

The farm area is irrigated. Formerly the water was distributed through a system of open channels resulting in wasteful and harmful seepage. During the past two years the majority of the open channels have been replaced by bume pipes. Plans have been drawn up for the proper drainage of the cultivated area which is a necessity.

Divisions of the Institute and its Sub-stations

The Institute now consists of the following Divisions:—

1. Agronomy
2. Botany
3. Soil Science & Agricultural Chemistry
4. Entomology
5. Mycology

6. Agricultural Engineering

7. Sugarcane Breeding (located at Coimbatore).

The Government of India also sanctioned the creation of the Division of Agricultural Economics as also the Division of Statistics as applied to field experimentation but they have not yet been started.

The Institute has now three substations :—

1. The Agricultural Substation at Karnal, including the Sugarcane Substation at Karnal;
2. The Botanical Substation at Pusa, comprising of the buildings and farm of the original Institute; and
3. The Sugarcane Breeding Station in Coimbatore.

The Institute had also temporary substations at Simla, Bhowali and Kufri which were financed by the Indian Council of Agricultural Research. On the establishment of the Central Potato Research Institute in the year 1949, these substations were transferred to the latter. However some facilities to continue the work on the breeding of rust resistant wheats will be provided by the Central Potato Research Institute. The Provision of land and other facilities at Simla for continuing the work on breeding wheat varieties resistant to rust, for maintaining crop collections and for fundamental agricultural research under soil and climatic conditions represented by the Himalayan regions is under consideration of Government. These facilities are a necessity.

The position which the Pusa Institute occupies in relation to the Provincial Agricultural Experimental Stations and Colleges is that of an institution for fundamental research and advanced post-graduate teaching institution. The position as regards the qualifications for admission to the post-graduate courses was reviewed in 1931, and on the advice of the Indian Council of Agricultural Research it has been decided that (1) distinguished graduates who have obtained the highest degree in science, short of a Doctor's degree, awarded by their University or an honours degree in science of a high standard or its equivalent; graduates of agricultural colleges who have passed in the first class or have otherwise attained a high position in the college gradation list; and selected officers of agricultural departments provided they are fully qualified to take advantage of the courses and are recommended by the Government of the province in which they may be serving; will in future be eligible for admission to these courses; and (2) that in each province there will be a selection committee on which due representation is given to universities and that the recommendations of such selection committees will go before a selection committee as the Institute which will have the final voice in the selection of students.

Two years' post-graduate courses of training are now provided in the following subjects :—

1. Agricultural Botany with special reference to (a) Plant Breeding and Genetics; (b) Cytogenetics; (c) Crop Physiology and (d) Economic Botany;
2. Agricultural Chemistry, Soil Science, Soil Microbiology and Soil Surveys;
3. Entomology with special reference to (a) Systematic Entomology; (b) Insect Ecology; (c) Insect Toxicology and (d) Parasitology;

4. Mycology and Plant Pathology with spécial reference to (a) Mycology; (b) Virus Diseases; (c) Plant Pathology; and (d) Plant Bacteriology;
5. Agronomy with special reference to (a) Soils, Crops and Manures; (b) Farm Management; (c) Agricultural Economics; (d) Cattle Management and Breeding; (e) Agricultural Statistics; (f) Demonstration and Propaganda; (g) Agricultural Machinery; and (h) Agrostology.

Upto the year 1945, there was only one-year course in Agronomy.

6. Sugarcane with special reference to (a) Genetics and Breeding; (b) Cytogenetics; (c) Physiology; and (d) Agronomy.

Although there is a demand for training in Agricultural Engineering from the Provinces and States, it has not been possible yet to start the courses due to lack of workshop facilities. The importance of research and advanced training in agricultural engineering cannot be over emphasised.

The two years' post-graduate courses include lectures, training in the methodology of research and in laboratory and field techniques. Field investigations are undertaken as part of the training in subjects where they are necessary. Regular examinations—theoretical, practical and oral—are conducted and in the final examination external examiners are associated. The number of students who have undergone the two years' post-graduate course of training in the years 1923-24 to 1948-49 are as follows:—

				Number of applications received	Number of admissions	Number of passed out
1923-24 to 1944-45 (21 years)	..	..	..	1,050	250	193
1945-46 to 1948-49 (4 years)	..	..	..	428	208	105

The accommodation in the existing hostel which was constructed in 1946-47 is 100 and this has limited the number of admission. The majority of the candidates are nominees of the provinces and states who recommend them for admission after scrutiny of their applications by their selection committees. Administrative sanction has been obtained for the construction of a second hostel for accommodation of another 100 students. It is expected that it will be constructed as soon as the financial position improves.

Associates of the Institute with very few exceptions have found employment in the agricultural departments and commodity committees and many of them have distinguished themselves as successful research workers and teachers and in other spheres.

Almost all the Indian universities recognize the Institute as a centre of research where their alumni can work for their doctorate degrees. Besides the regular two years' post-graduate course, facilities are offered for short refresher courses of varying durations to those who are recommended by the provincial or state departments of agriculture. The students of the former Imperial Animal Husbandry Institute (now the Indian Dairy Research Institute) also receive training at this Institute for a period of three months in Estate Management, Farm Management, Plant and Animal Breeding etc.

The Hon'ble the Prime Minister during his visit to the Institute in April 1949 suggested that a short course in agriculture should be organised at the Institute for the benefit of the younger scientists working in the State Departments of Agriculture. In pursuance of this proposal it has been decided that there should be two series of short courses regularly conducted at the Institute, *viz.*, (a) a three months' refresher course in any of the main branches of agricultural science, and (b) a six weeks' course, devoted mainly to advanced work in agronomy specially suitable for younger scientists such as District Officers. Enquiries made by the Ministry of Agriculture have shown that there is a sufficient demand from the States to justify the opening of these courses, which will replace the *ad hoc* short courses referred to in the previous paragraph.

6 months' course of training in soil survey and land utilization has been started at the Institute. The syllabus of the course include (a) Soil Genesis, Physical Geography and Soil Fertility; (b) Survey Science; (c) Soil and Water Conservation and Land Utilization; (d) Survey (Field Work); and (e) Cartography (Laboratory).

In addition, honorary research workers are allowed to carry on research in the Institute's laboratories. The number of men who have taken advantage of these facilities is not inconsiderable. Since 1946-47, four Research Fellows (who are paid Rs. 150/- per mensem) are appointed every year generally from among the Associates of the Institute to carry on independent research.

Five members of the research staff of the Chemistry Division of this Institute and one student (a Chinese Govt. Scholar) of the Botany Division obtained Ph.D. degree on this work at this Institute during the period 1945-48.

Participation in scientific activities in India and other countries : Contact with Scientific Organisation.

Scientific workers of a country have an important field of activity outside their work in the establishment to which they belong. As members of the learned scientific societies, they participate in the development and organisation of the science they profess. As members of scientific committees or as expert members of other committees or in their individual capacity they advise official and non-official organisations on scientific matters, the survey of the country's resources and in the formulation and implementation of programmes of development. The staff of this Institute have participated in all these, and during the past three years they are participating in an increasing measure in such activities. Quite a number of them hold responsible positions in scientific societies in India, such as, the National Institute of Sciences of India; the Indian Botanical Society; the Indian Chemical Society; the Indian Societies of Phytopathology, of Soil Science, of Entomology, of Plant Breeding and Genetics; the Indian Science Congress Association and others.

In the field of coordination and planning of research and in the development of agriculture, they help the Ministry of Agriculture, the I.C.A.R., the I.C.S.C. and other Commodity Committees in this work as members of the scientific and other committees of these bodies. Some members of the Institute also render similar help to several committees appointed by other Ministries of the Government.

With the realisation of the importance of science in peace and defence and in the development of natural resources and amenities of life and as a result of the two world wars, the pace of scientific progress has been tremendously

accelerated. Scientists have, therefore, to make redoubled efforts to keep abreast of developments of their respective subjects and of science in general. Periodic conferences of scientific workers are of great help in this respect. International conferences play a similar part in a larger sphere. The scientific staff of the Institute have opportunities to participate in such conferences in India and some of them have been members of delegations of scientists sent by the Government of India to attend International Conferences.

Other lines of international contact of science which is also of economic benefit to the countries concerned are the exchange of information, specimens, samples, plant materials etc. between research institutes and individual scientists. These contacts have been greatly strengthened in recent years.

In the past few years, the following members of the staff have participated in international activities as detailed below:—

1944 Dr. B. P. Pal, Head of the Division of Botany, visited China on the Goodwill Scientific Mission sent by the Government of India.

1946 Dr. J. N. Mukherjee, Director, represented the Government of India, Department of Agriculture on the Royal Society—Empire Scientific Conference, the British Commonwealth Scientific Conference, and the Imperial Agricultural Bureaux Review Conference at London.

He also attended the meetings of the General Assembly of the International Council of Scientific Unions and was elected a member of the Executive Committee of the said Council.

1948 Dr. J. N. Mukherjee, Director and Dr. T. J. Mirchandani, Head of the Division of Agronomy attended on behalf of the Government of India, the meetings of the First Commonwealth Conference on Tropical and Sub-Tropical Soils held in Harpenden, England.

1949 Dr. J. N. Mukherjee, Director, attended the United Nations Scientific Conference on the Utilization of Resources held at Lake Success, U.S.A.

He also attended the meetings of the General Assembly and the Executive Committee of the International Council of Scientific Unions held at Copenhagen.

Dr. B. P. Pal, Assistant Director and Head of the Division of Botany visited Australia as a member of the Indian Scientific Delegation sent by the Government of India.

Dr. R. V. Tamhane, Soil Survey Officer, attended the Specialist Conference in Agriculture on Plant and Animal Nutrition in relation to Soil and Climatic Factors held in Adelaide, Australia.

From the information given in the preceding pages about the development of the Institute it will be seen that the Institute has played a unique part in the development and reorganisation of agricultural research and training in India. It has also been a nursery wherefrom many important agricultural research organisations of this country have emerged.

In the next part of this Report the main results of the research work of the Institute have been recorded in three periods; 1905-1936 while the Institute was at Pusa (Bihar); 1936-45 at Delhi before the reorganisation of the Institute, and 1945-48 at Delhi after the reorganisation.

MAIN RESULTS OF RESEARCH WORK OF THE INSTITUTE FROM 1905—1948 (IN THREE PERIODS).

As mentioned in the introduction and again at the end of the first section, this annual report contains a summary of the research work done by this Institute from its inception up to the end of the crop year 1947-48. This summary, which follows immediately, is divided into the three periods that naturally suggest themselves. Some account of the first period, i.e., whilst the Institute was still at Pusa, was given on a previous occasion, in the annual report of this Institute for the year 1936-37; this has been re-written and a narrative given of work in the two subsequent periods.

The greatest interest will perhaps attach to the third or present period, starting from October 1945 when the Institute entered a phase of expansion. In spite of the obstacles referred to in the introduction, caused by delays in recruitment of staff and difficulties in obtaining equipment and apparatus, lacunæ in the previous research and training programme of the Institute were filled and important new lines of investigation may afford a representative cross-section of present day thought and work in the agricultural sciences.

The new investigations cover such subjects as agrostology and the improvement of forage crops and pastures; experiments on "cultivators holdings" in the Division of Agronomy; breeding crop strains for varying levels of soil fertility, introduction and trial of promising economic plants obtained from abroad and a varieties from within the country which are not well-known or fully exploited, studies on growth hormones, weedicides, and fundamental cytological studies in the Division of Botany; breeding of disease-resistant sugarcane and the intensive collection of the important wild species *S. spontaneum* at the Sugarcane Breeding Station, Coimbatore; systematic soil surveys including that of the Institute farm and that of the Agricultural Substation, Karnal, studies on micro-nutrient elements using modern techniques, studies of clays and clay minerals, and synthesis of insecticides and fungicides, studies on soil enzymes and nutritive value of good crops, cattle feeds and fodder including vitamin assays in the Division of Chemistry; investigations on insect ecology and toxicology in the Division of Entomology; assessment of damage caused by the more important diseases of crop plants and studies of antibiosis in the Division of Mycology. The Division of Agricultural Engineering, as already pointed out, began its existence only towards the close of 1945.

A note on wheat rusts and their control, prepared in 1947 after the severe epidemic of black rust in Central and Peninsular India, by the Division of Botany and Mycology at the instance of the Director, served as the basis of an All-India Coordinated Wheat rust Control Scheme which was sanctioned later.

DIVISION OF AGRONOMY

Introduction

Agronomy is the art and science of crop and animal husbandry. It deals with the scientific, technical, social and economic aspects of agriculture and involves an integrated study of soils, crops, manures, water supply, drainage, irrigation and livestock in their climatic setting: diseases and pests of crops; their nutritive value as fodders and feeds and all other factors, the control of which is of significance for the life of the rural community in particular. Thus the chief aim of the Division of Agronomy is the improvement and raising of the standard of life of the peasant.

The peasant's economic status is bound up with the question of the high yields of crops, low production costs, maximum profit from stock and the efficient utilization of his spare time and resources. This can be achieved by the application of the methods and the results of science to his problems. One of the most pressing problems of the country is the low fertility of the land, caused by constant exhaustion of the soil. More knowledge is required about the relative fertilizing value of compost, farmyard manure, green manures, varieties of cakes and artificials; useful rotations, and crops capable of maintaining the fertility level of the soil; also about mixed cropping, pasture management, grass and legume mixtures for fodder and soil improvement in leys and their manuring; efficient utilization of rain, flood, under-ground and flow irrigation water for raising food, cash, forage and pasture crops to supply food to man and cattle and raw materials for the industry. Last, but not the least, knowledge is also required as regards suitable methods of selection, management and handling of the stock.

Keeping these objects more or less in view, the experimental work on crop and animal husbandry has been in progress in this Institute for over four decades. The famous Sahiwal herd for milk and Tharparkar for both draught purposes and milk production are being maintained respectively at Delhi and Karnal. Permanent manurial trials (at Pusa), extending over thirty seven years, where cumulative effect of organic and inorganic manuring treatments, green manures and leguminous crops in rotation for raising basic soil fertility in relation to climatic factors, and for studying trends of its changes with time are in progress. Experiments on cultivators' holdings of an optimum size for a medium-sized family have been laid down quite recently to test local rotations against balanced cash-food-fodder crop rotations. Experiments on crop rotations and on large, medium and small sized holdings are also underway. About 1,500 living specimens of indigenous and exotic grass and seeds have been collected of which about 400 have been established. Similar collections of cultivated and wild legumes have been made to test their suitability as fodder, for pastures, erosion control and green manure (legumes). Additions are being made to them.

The first period (1905-36) at Pusa, Bihar.

Experiments other than sugarcane and berseem were under rainfed conditions.

The main lines of investigations were (1) Varietal trials on crops including sugarcane (2) fodder and forage crops (3) crop rotations (4) manurial experiments (5) farm machinery and implements and (6) cattle breeding.

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1. (a) *Cereals and legumes*.—Varietal trials with large number of crops under field conditions demonstrated definitely the high yielding capacity of the following varieties produced at the Institute.

Maize	P.F. 3
Gram	P.F. 11
Soyabean	P.F. 2
Peas	P.F. 2 and P.F. 3
Wheat	Botanical Section Type 52
Barley	" " Type 21
Oats	" " Nos. 1 & 2

(b) *Sugarcane*.—More than 300 varieties of cane were tried at Pusa and the original selection and distribution of the famous canes Co. 210, Co. 213 and Co. 214 were made by which the Indian sugar industry grew up. Other successful selections were Co. 281, Co. 285, Co. 299 and Co. 331. A technique of sugarcane cultivation was developed by which it was possible to obtain a higher yield at a cheaper cost. The method is as follows:

The land for cane cultivation is green manured in the preceding *Kharif* with sannhemp to which double superphosphate (40 per cent P_2O_5) is added at the rate of 2 mds./acre. The soil is worked thoroughly during the *rabi* and kept closed to retain moisture. At the time of planting, furrows are opened with a double mouldboard plough fitted with a subsoiler working directly behind it. The distance between the row varies according to the varieties—3 feet in the case of medium and thick and $2\frac{1}{2}$ feet for the thin canes. Before planting oil cake meal (5 per cent. N) at the rate of 10 mds./acre is spread evenly in the furrows. After the cane setts have been placed 'eye to eye' the soil gathers with roller is drawn over the furrows, filling them up, covering and pressing the setts. The intercultural operations are started just after the germination of the cane. The work is done cheaply and satisfactorily with a cultivator which is drawn between the rows by a pair of bullocks. The operation is repeated several times till the break of monsoon when the crop is finally ridged up with the double mouldboard plough. No further operations are required till the time of harvest.

The method has been adopted successfully at Delhi.

2. *Fodder and forage crops*.—A large number of fodder grasses from all parts of the world were grown and tested. They did well in the monsoon when there were other fodder grasses in abundance but were of no value in hot weather. Berseem, proved to be the best irrigated winter fodder crop for the milch herd and guar, cowpeas, *meth* and soybean as hot weather and monsoon fodders. The following grazing cycle of green fodders was found very suitable for the herd:

<i>Crop</i>	<i>Month</i>
<i>Gur</i>	August
Cowpeas	September
<i>Meth</i>	October
Soyabean	November
Berseem	December to April
Maize and <i>Meth</i>	May to July

3. *Crop rotations*.—Under unirrigated conditions in Pusa the following rotation after many years run was found very suitable :

<i>Season</i>	<i>First Year</i>	<i>Second Year</i>	<i>Third Year</i>
Kharif	Maize for fodder	Maize for seed	Legumes
Rabi	Oats	Rahar and Gram	Oats

The yield obtained from different crops in different years showed that the fertility of the land was considerably increased under such rotations.

4. *Manurial Experiments*

(a) *Permanent manurial and rotational experiments :*

These experiments were laid down at Pusa in 1908 according to the scheme formulated by the Board of Agriculture with a view to study the conditions which determine soil fertility and the manner in which soil fertility is affected by the application of important manures, including green manures and by rotation of crops. The results obtained upto the year 1918-19 were discussed by a sub-committee of the Board of Agriculture in 1919. A sub-committee of the Board of Agriculture held in 1929 examined the question of the continuance of these experiments and made certain alterations in the scheme which have been followed since 1930-31. The experiments have recently been made the subject of more intensive study. The results and conclusions of these experiments are discussed later.

(b) *Manurial trials of cereals and legumes :*

Rape cake, F.Y.M., superphosphate, ammonium sulphate and potassium sulphate were tried singly and in various combinations on maize, oats, wheat, peas and gram. With cereals it was found that the following three treatments : (i) rape, cake, (ii) F.Y.M., (iii) ammonium sulphate with superphosphate and potassium sulphate, (iv) ammonium sulphate with superphosphate gave better results than other treatments while potassium sulphate alone had a depressing effect. With peas and gram, the results were similar with the difference that the plots treated with superphosphate alone gave equally good yield.

(c) *Manurial trials on sugarcane :*

Farmyard Manure at the rate of 14 tons per acre and green manuring with sannhemp followed by superphosphate at 50 lbs. P_2O_5 per acre and rape cake at 40 lbs. N per acre promoted maximum yield of sugarcane. It was also observed that there was no deterioration in the quality of the juice from these treatments.

(d) *Green manuring experiments :*

Green manuring experiments with sannhemp, cowpeas, soybean, velvet beans, meth and guar were conducted on wheat. Plots green manured with sannhemp, cowpeas and velvet bean gave significantly more yield than others.

5. Farm machinery and equipment.

Both mechanical and animal power driven machines manufactured in India and abroad were tested and the following recommended to interested farmers :—

(a) *Tractors*.—McCormick Deering 15½30 H.P. kerosene oil tractor and Lenz Bulldog 15½30 H.P. crude oil tractor.

(b) *Tractor implements*.—(a) Plough : Ransomes' Consul series 3. furrow, 4. furrow and 5. furrow mould board type. (b) Disc harrows : Ramsomes' Baron tandem and Baronet types, sizes—8' and 10'. (c) Cultivator : International 13 tine or Ransomes' Orwell 11 tine (d) Seed drill : Amsco self lift disc coulter 8' wide.

(c) *Bullock implements*.—(a) Plough : Ransomes' all steel victory (b) Cultivator : Raja spring tooth harrow—5. tine and 7 tine (c) Seed drill; Gujrat type (d) Land leveller: Sindhi type made at Pusa.

(d) *Carts*.—Wooden bodies designed at Pusa fitted with the Dunlop pneumatic equipment.

6. Cattle Breeding.

(a) Selection.

The importance of cattle breeding in the improvement of agricultural economy of the country is well realised. The average milk yield of Indian cow is as low as 2 lbs. a day.

The Pusa pedigree Sahiwal herd started in 1904 with 14 cows and 1 bull. By gradual selection from the homeherd stock with fresh blood from occasional outside purchases the overall average milk yield per cow in milk per day was raised from 5.8 lbs. in 1913-14 to 13.6 lbs. in 1931-32. In 1932-33 four times milking instead of usual twice was started and no ill effect was noticed on the health of the cows. The milk yield rose to 20.7 lbs. by 1935-37.

(b) *Early Maturity Experiments*.—Experiments to bring about early maturity in the progeny of the herd was started in 1932. This has been successfully induced by special feeding and bulls now serve at 1 year 7 months instead of at 3 years and heifers take a bull at the age of 1 year 6 months to 1 year 8 months instead of at 2½ years.

There were a few cases of foot and mouth disease in cattle during this period.

The second period (1936-45) under irrigated conditions.

The main lines of investigation were the same as those being carried out at Pusa plus the following: berseem seed set, flood water farming, mixed farming and artificial milching.

1. Varietal Trials.

(a) *Cereals and legumes*.—The undermentioned varieties of different crops proved their high yielding capacity under Delhi conditions:—

Wheat	C518, I.P. 125 and I.P. 165
Barley	I.P. 13
Oats	I.P. 1 and I.P. hybrid x 27
Gram	I.P. 58, I.P. 25 and I.P. 53
Cowpeas	Nos. 585, 598 and 397

(b) *Sugarcane*.—The undermentioned varieties have shown good yields with high sucrose content :—

Cos 428, 457, 421, 444, 443, 540, 537, 423, 446, 450, 454, 435, 419

The following showed resistance to frost in the order named :—

Cos 453, 537, 538, 356 and 396.

2. Forage Crops and Grasses.

(a) *Forage crops*.—Sorghum, maize and cowpeas constitute the main kharif crop and berseem the main *rabi* crop both at Delhi and Karnal. Long term yield trials showed that among cowpea varieties No. 337 and No. 700 are good green fodder varieties.

(b) *Grasses*.—During 1942 and 1943, 1500 living grass specimens as well as seeds were collected from the different provinces and states. Out of this collection, 406 were established and out of these only 80 had been identified. Several of these were found to be promising for fodder and pasture.

3. Manurial Experiments.

(a) Permanent manurial and rotational experiments at Pusa (Bihar).

The results for Series B are shown in diagram (attached). The main conclusions are summarized below :—

Effect of organic manures.—(i) Bulky organic manures had a very appreciable effect in increasing the total crop, but whereas with cereals the production of grain was materially increased, the reverse was the case with *rahar*. (ii) The residual effect of the rape cake was inappreciable on the second crop although its effect on the crop to which it was applied was very marked. Rape cake was not as effective as farmyard manure when the application was made only once in a full cropping season.

Effect of mineral manures.—(i) Of the manurial constituents, nitrogen, potash and phosphoric acid when applied alone, the last mentioned was the only one which has distinctly positive reaction in the Pusa soil but the combination of all three gave best results with the crop to which it was applied. (ii) In the case of cereals, the use of phosphoric acid increased the proportion of grain but in the case of *rahar* all manures increased the proportion of green matter.

Effect of green manures.—The effect of green manures on cereal was definite and distinct, and still more so when in combination with phosphoric acid. The yield of *rahar*, however, decreased under the influence of a combination of green manure and phosphoric acid.

Effect of inclusion of legume in rotation.—Positive influence of legume on the yield of subsequent crop in the rotation was indicated.

Nitrogenous manuring experiments (Russell Experiments) at Delhi.—Experiment to determine the relative values of nitrogen in different organic manures and inorganic fertilizers, estimation of their recovery by crop and changes brought about in the soil was initiated in 1941 on the recommendations of Sir John Russell. A second series of experiments in a more uniform field with an increased dose of nitrogen of 40 lbs. per acre and with inclusion of two green manure crops were set up in 1944-45. The investigations are being carried out in collaboration with the Division of Soil Science and Agricultural Chemistry. It is too early to arrive at any conclusion but the data obtained so far indicate that better response is obtained when the fertilizers are applied in inorganic forms or when organic manures are supplemented with inorganic nitrogen. The experiments are being continued.

(c) *Berseem manurial experiment (Delhi).*—This experiment was started in 1940-41 to study the effect of various fertilizers and manures on the yield and nutritive value of berseem fodder and yield of seed and the residual effects on succeeding crops. Evidence has been obtained from this experiment that phosphatic manuring not only provided higher yields of berseem rich in P_2O_5 and CaO but that it also builds up soil fertility of benefit to cereal crops which may follow the phosphate manured berseem :

	Average yields of green fodder lbs. per acre			Yield of wheat (cow- pea-wheat rotation)	
	1940-41	1941-42	1942-43	1943-44	1944-45
F. Y. M. 80 lbs. N	31,680	24,426	23,748	20.91	18.05
Rape cake lbs.	34,178	23,984	24,442	16.12	15.03
$(NH_4) 2SO_4$ lbs.	21,432	12,150	8,145	15.23	16.73
Super at 132 lbs. P_2O_5	36,609	21,413	25,031	24.18	27.31
Super at 198 lbs. P_2O_5	37,183	23,445	30,414	26.16	32.61
Super 264 lbs. P_2O_5	37,696	24,565	28,677	25.53	36.10
No manure	17,176	13,540	8,979	14.94	14.65

Note: Manuring was stopped after 1942-43. Wheat crop was grown without manure.

(d) *Manurial experiment with paddy (Karnal).*—These experiments conducted at Karnal showed that plots treated with sulphate of ammonia at 40 lbs. N per acre singly or in combination with sodium nitrate gave significantly higher yields over plots treated with the latter fertilizer alone or over no manure plots. The introduction of berseem in the rotation increased the yields of paddy considerably but made the influence of these nitrogenous fertilizers indicating that for the levels of yields obtained berseem in the rotation produced similar effects as these fertilizers.

(e) *Green manuring experiments.*—(i) A series of experiments were conducted both at Delhi and Karnal to examine the effects of leguminous and non-leguminous green manure crops both with and without the application of fertilizers on the yields of wheat. Of the legumes cowpeas and sannhemp have shown up better than the non-legumes, such as sorghum and maize. The addition of fertilizers, notably sulphate and ammonia gave increased yields of wheat. At Karnal the application of sulphate of ammonia or superphosphate in a field green manured with berseem increased the yields of wheat only by $\frac{1}{2}$ to 1 maund per acre in 1944-45, but a dressing with both these fertilizers increased the yields by 6 or 7 maunds per acre.

(ii) Two small holdings of 8 acres and seven and half acres are being run at Delhi to see the effect on total crop yield of rotations containing 50 per cent. and 66.6 per cent. intensities of green manuring. In the light of experience gained from these experiments since 1941-42 some modifications in the cropping system was introduced. These experiments are being continued. The results are discussed on page .

4. *Seed production in berseem.*—The results of three years experiments to ascertain the number of cuttings that could be taken for the optimum production of seed showed that maximum quantity is obtained by leaving the crop to seed after the 3rd cut in February.

5. *Flood water farming experiments.*—The effectiveness of flooding land in August or September with about 10 inches of surplus water against a *barani* or rainfed condition in increasing crop production was shown. These yields can be further augmented by conserving the soil moisture by covering the flooded land with sannhemp or any other mulching material which can be buried in as green manure the year following :—

							Average yields of wheat grain (I. P. 4) Mds. per acre (1941-42 to 1943-44)	
							Mulched	Non-mulched
Karnal : flooded	..	..	..	..	..	..	17.30	13.3
Rainfed	..	..	..	..	..	..	10.93	7.99
Delhi : flooded	..	..	..	..	..	..	7.04	6.43
Rainfed.	..	..	..	..	..	..	5.08	5.78

6. *Artificial mulching.*—These experiments were carried out both at Karnal and Delhi to study the effect of artificial mulching with sugarcane or other green manure crop on the yield of sugarcane, wheat, barley, and gram. Significant increases in yield of these crops have been obtained from the mulched other than the unmulched fields.

7. *Farm machinery and equipment.*—(a) *Designing of Combines :* After actual determination of the draw bar pull of the different tractor drawn implements it was found that the implements used were below the normal load of the tractors. A tillage combine and a seeding combine with three drills was designed and assembled. These worked satisfactorily with reduction in cost of tillage and sowing.

(b) *Dynamometer tests with Indian ploughs :* 40 Indian ploughs collected from different parts of India have been examined from constructional, draw-bar pull, depth of ploughing, resistance per unit area of cross section of furrows and H.P. and classified.

8. *Cattle breeding.*—The work with the Pedigree Sahiwal herd continued on the same lines developed at Pusa. Introduction of these principles to the Tharparkar herd (dual purpose) at Karnal resulted also in a remarkable improvement in yield, the average milk yield per cow per day having risen from 14.4 lbs in 1935-36 to over 20 lbs in 1944-45.

Many cows have been bred with over 10,000 lbs. milk yield per lactation of 306 days. The highest recorded was 12,312 lbs. from 'Chansuri' in her 6th lactation in the Sahiwal herd.

The introduction of standardised milk for feeding calves has resulted in a considerable decrease in the cost of calf-rearing. The milk is standardised to 3.5 per cent. fat with skimmed milk.

The Present Period (1945-48) :

The work of the Division is concentrated on the following lines :—

1. Crop husbandry; 2. Manurial experiments; 3. Cultural experiments;
4. Utilization of flood water; 5. Cultivator's holding; 6. Agro-tology : Selection of grasses and legumes for improvement of pastures, introduction in crop rotations, control of erosion; 7. Reclamation of saline patches; and 8. Animal husbandry. Of these item 5, 6 and 7 have been recently introduced.

1. Crop Husbandry :

(a) *Varietal trial*.—(i) Among the new wheat varieties NP 720 yielded either better or was comparable in yield to N.P. 165 and C513. Other promising wheats with yields comparable to NP 165 were NP 775 and NP 733. The trial will have to be repeated before conclusions are drawn.

(ii) Among cane varieties the following showed good yields with high sucrose content: Co. 312, Co. 421, Co. 453, Co. 537, Co. 620, Co. 621, and Co. 622,

(iii) New potato hybrids H 209 and H 208 exhibited better outturn than *Phulwa* or *Gola* varieties.

(b) *Crop rotations*.—Rotational experiments conducted at Pusa and at Delhi respectively in the Permanent Manurial Series and in intensity of green manuring experiments have indicated the following (i) Inclusion of legume crops such as gram and peas in the rotation improves soil productivity and thereby increases the outturn of the succeeding crop.

(ii) Application of phosphate to legume crops increases the nutritive value of the various crops in rotations.

2. Manurial Experiments :

Lack of nitrogen, phosphorous and organic matter are the major limiting factors in realization of higher yields of crops in India. Manurial Experiments are in progress to ascertain how to build up soil fertility and to improve crop yields. The results are as under:—

(a) *Permanent manurial and rotational experiments*.—The experiments have been continued at Pusa. From the year 1947 they are being conducted in collaboration with the Division of Soil Science and Agricultural Chemistry and the Division of Botany. The conclusions are the same as discussed in Part II of the report.

(b) *Nitrogenous manuring experiment (Russell experiment)*:—As reported earlier the experiments were started in 1941 and due to low dosage of fertilizers used and wide variations in soil fertility of the experimental plots the scheme was revised in 1945. These experiments have been continued but the results obtained in most of the years are still not significant.

(c) *Green manuring experiments*.—(i) Indications have been obtained that highest yield of succeeding wheat was obtained from plots where green manure was grown and buried *in situ* as compared with green manure grown in another field but buried in the experimental plots or grown in another field but buried in experimental plots after composting.

Treatment	Yield of wheat in mds. per acre 1948-49		
	O	N	P
No green manure	11.64	15.77	11.2
Green manure grown and buried <i>in situ</i>	18.9	18.8	20.24
Green manure grown in another field but buried in experimental plots (200 mds. green per acre)	13.18	17.39	10.70
Green manure grown in another field but buried after composting (from 200 mds. green/acre)	13.95	13.93	17.14

(ii) The results of experiments on green manuring intensity and yield of crops in rotation were as under :—

Name of crop	Yield in Mds/acre (Average of 7 years) 1941-42 to 1947-48		
	Holding with manure	Holding with one green manure in two years	Holding with two green manure in 3 years
Cereals	18.91	24.98	27.07
Pulses	13.25	13.44	16.49
Green fodder	232.64	294.34	293.43
Cotton	7.05	9.33	11.01

Thus the yields of cereals, pulses and fodder in the rotation are improved by intensive green manuring.

(d) *Manurial Experiment on Paddy*.—Direct manuring of paddy with 40 lbs. N as ammonium sulphate resulted in increased yield of paddy by 4.7 mds./acre. Application of 80 lbs. P_2O_5 also increased the yield by 1.7 mds./acre. Both these together gave an increase in yield of 7.2 mds./acre.

(e) *Phosphatic manuring of legumes*.—(i) Building soil fertility : Several experiments are in progress to study further the important effect of phosphatic manuring of berseem in building up soil fertility. The results from one experiment are given below: (the figures in rupees are based on the prices obtaining in the year 1946).

Superphosphate added in 3 years					Total increase in yield of wheat/acre over no manure in 3 years.		Cost of super. added @ Rs. 10/5/6 per md.		Value of increase in grain and straw wheat @ Rs. 10 per md. and straw Re. 1 per md.	Differ- ence (gain)
					Grain	Straw	Rs.			Rs.
12 maunds	..	..	..	..	29.6	54.2	124.1		350.2	+226.1
18 maunds	..	..	..	..	42.3	79.4	186.1		502.4	+316.3
24 maunds	..	..	..	..	45.7	82.4	248.2		539.8	+291.6

This shows that application of superphosphate ranging from 12 to 24 maunds in 3 years helps in building up soil fertility and increasing yield of succeeding 3 wheat crops.

The above relates to experiment C on page 20 which was started in the second period and completed in the present period.

(ii) *Low doses of phosphate*.—By carrying out experiments with low doses of phosphate it has been found that it is economical to dress 64 lbs. P_2O_5 or 2 maunds of triple super./acre for manuring berseem for fodder.

(iii) *Different forms of phosphatic fertilizers*.—Experiment to determine response in fodder yield of berseem to various forms of phosphates such as superphosphate, triple superphosphate, ammonium phosphate, bone-meal, bone meal sulphur compost, rock phosphate, Trichi nodules and basic slag on legumes grown in rotation with cereals. The best results were obtained with ammonium

phosphate, which confirm previous observations that ammonium sulphate and super are better than super alone (in fact ammonium phosphate proved to be better than ammonium sulphate plus super), which seems to indicate the need for adding a dose of nitrogen in the initial stages of growth of the legumes. Even better responses were obtained with super-phosphates applied in combination with farmyard manure. Potash in combination with phosphates also gave encouraging results.

(iv) *Legumes other than berseem*.—Experiments on the manuring of other legumes with phosphates have shown that *Shaftal*, *Methra* and peas do respond to phosphate manuring.

(f) *Fertilizer placement experiment*.—Definite economy by placement of fertilizers has been indicated by higher yields of *guar* fodder with half the quantity of placed fertilizer compared to the full quantity broadcasted.

3. Cultural Experiments :

(i) *Tillage*.—The results of the tillage experiments carried out at Karnal have shown that tractor cultivation gave lower yields than the cultivation by Victory cum country plough, or country plough in two out of 3 years. The highest yield was obtained from the Victory cum country plough.

(ii) *Studies on gram wilt*.—Great damage is done to the gram crop every year by the wilt disease. The cause of this has not been satisfactorily elucidated nor are any efficient control measures known. A cooperative experiment has been initiated in which the Divisions of Agronomy, Chemistry, Mycology and Botany are taking part. In agronomical investigations it has been found that early November sowing gave lower incidence of wilt and higher yields than either October or December sowings.

(iii) *Spacing*.—Potatoes when sown at 9" from tuber to tuber gave maximum yields.

4. Utilization of flood water :

This experiment on the utilization of surplus water in the canal or river during August or September for irrigating and conserving soil moisture was continued. Results corroborated earlier findings.

5. Cultivator's holdings :

These investigations are an attempt to make an integrated approach to the problems of agriculture with special reference to small farmers. As such, the size of these holdings has been limited to 6 acres. This area is utilized to grow cereals, pulses, cash, feed and fodder crops enough for balanced feeding of the family and the stock. Comparison of five holdings at Delhi and five at Karnal have been laid out. The cropping is different for barani and irrigated ones. The principal cereal crop is wheat except in one holding at Karnal where rice forms the cereal crop. Maize is grown to supplement wheat, cash crops are cotton and sugarcane. Legumes in two holdings are manured with phosphate and the entire performance is compared with holdings without phosphate manuring of legumes. Thus results of these holdings will provide overall data in production and economic returns, when compared with indigenous system followed by the peasant.

6. *Agrostology* :

With the starting of this section in 1946 the scope of studies and experiments on grasses and also legume have been considerably increased.

- (a) Grass nursery—A grass nursery with 45 indigenous and 15 exotic species of grasses has been established. From observations on these, 15 species have been found promising. These 15 species along with 5 well known Australian grasses are being tested for their fodder yielding capacity under irrigated and non-irrigated conditions.
- (b) Manurial trial with *Setaria palmaefolia*.—This grass has been found especially promising as it is very nutritious and contains an exceptionally high protein content and in this quality surpasses all the known Indian grasses and compares very favourably with some of the renowned exotic grasses. It is under trial to test the effect of fertilizers on its fodder yield under irrigated conditions.
- (c) Ley farming experiments—Under this system of farming, grasses in combination with legumes are grown in leys of one, two or three years' duration under suitable fertilizer treatments for the production of protein-rich fodder and for the improvement of soil fertility. Experiments were started in 1945-46 with a mixture of Rhodes grass and lucerne, and various fertilizer combinations of nitrogen, phosphate and potash. The ley remained in the field for three years after which it was ploughed down and followed up with maize-wheat-maize. The fertilizer treatments given to the ley indicate that nitrogen alone and in combination with phosphate and potash produce marked response from the grass, while phosphate increases the yield of lucerne. Bonemeal treatment, however, had a depressing effect. The residual response is now being studied on cereal crops.
- (d) Legume nursery—Since legumes play an important role in the fertility building experiments a nursery with 30 species, so far collected, had been established.

7. *Control of Salinity* :

The farms at Delhi and Karnal are in the semi-arid zone and for successful farming the land has to be irrigated. Because of the injudicious use of irrigation water in the past and of the conveyance losses through seepage in the earth irrigation channels, there has been a raise in the water table resulting in water-logging and development of salinity. This has now assumed proportions as to limit production of high yields in many plots.

To prevent further seepage losses the major conveyance channels have been replaced by hume pipes or open concrete channels. Programme of work has been drawn up jointly with the Division of Soil Science and Agricultural Chemistry on (i) water requirements of crops under Delhi conditions so that the exact quantity of irrigation water required for raising different crops supplementing rainfall can be added and thus reduce the risks of water logging (ii) reclamation of the already saline plots through drainage, chemical treatments including gypsum and sulphur and also a cropping system with grasses and legumes in rotation.

The work of improvement continued and is concentrated on the following lines:

Line breeding :—Maintaining 50 per cent. blood of the grand parent in the progeny to maintain pure breed.

Selection :—Culling out (rejecting) of stock which are below the standard either in milk, yield, size, constitution or colour and maintaining only the best ones.

Weaning :—Removing the calves from the dam at birth and rearing by hand feeding to improve milk temperament in the cow, in order to estimate the maximum production capacity, and to ascertain the daily rate of growth and the minimum quantity of milk required per day for growth and maintenance of calves.

Scientific feeding :—Feeding concentrates with protein of high biological values for milk production and growth and rich green succulent fodders containing legumes, for maintenance.

Four-times milking :—To increase the production capacity of a cow and maintain persistency in milk yield; to prevent mastitis and milk fever in milking stock.

Early maturity :—To increase the production life of cows, by two or three years, to test the heifers before 3½ years and bulls by 15 years.

Precalving milking :—It gives an early heavy flush and develop milking temperament in the heifer milked without calves and to prevent mastitis and milk fever.

Handling of cattle :—To develop docile and milking temperaments.

As a result of this work following improvements have been achieved :—

1. Mating average has been reduced to 18 months in case of heifers with live weight of 600 lbs. Bulls are put to service at an age of two years with live weight of 800 to 850 lbs.
2. Premilking has prevented mastitis and milk fever. The treatment also brings the cows into heavy flush soon after calving.
3. Improvement achieved in the Sahiwal herd can be seen from the table below :—

Treatment	Wet average lbs.	Overall average lbs.	Percent cows in milk	Dry period
1994-14*	5.0 to 10.5	2.0 to 5.5	40 to 51.7	Over 200 days
1915-31†	10.5 to 12.6	5.9 to 6.0	49.8 to 57.1	Do.
1932-40‡	17.5 to 22.3	9.2 to 15.6	52.7 to 70.8	93 to 160 days
1941-48	18.7 to 20.7	12.4 to 13.7	61.7 to 70.00	Do.

Tamili is one of the best cows in the Dairy. She gave a yield of 12,384 lbs. of milk in a lactation during the above period.

Similar improvement in the various directions has been effected in Tharparkar herd at Karnal. The milk yield has gone up from 8.0 lbs. to 20.5 lbs. per cow per day. In spite of this increase in milk yield the draught quality of the bullocks for this herd has not suffered a setback to any extent.

*No weaning at birth.

†Weaning at birth was started in 1915.

‡Four times milking was introduced in 1932.

DIVISION OF BOTANY

MAIN RESULTS OF RESEARCH FROM 1905-48.

The first period (1905-36)

The turn of the last century marked the beginning of the application of genetic principles to plant breeding. Attempts were made in the agriculturally-advanced countries to systematise the methods of crop improvement and to place them on a scientific basis. In India also similar work was taken up in 1905 when the Botany Division of the Indian Agricultural Research Institute was organised by the well-known scientists, Sir Albert Howard, and Mrs. G. L. C. Howard. Before the Howards commenced their classical researches on Indian crops, hardly any work had been done in economic botany in India; the crops that were grown at that time often consisted of mixtures of different types, good, bad, or indifferent in their performance. Yields from such mixtures naturally tended to be low and highly variable and the quality of the produce was poor, especially for the requirements of the export market. The first step in the amelioration of these conditions was to isolate pure types and to study critically their performance with a view to selecting the superior strains.

Collections of crop plants, therefore, began to be recognized as a necessary preliminary for undertaking breeding work on crop plants. Arrangements were, therefore, made to obtain as many samples as possible of the varieties cultivated in the country, partly by direct collection and partly by writing to the Directors of Agriculture and Economic Botanists situated in the various provinces and states.

The collections were studied at Pusa; duplicates were eliminated and from the resultant pure lines the best agronomic types were selected and put into varietal trials. As a result of such work a large number of pure strains became available not only for the use of the Institute itself but also for the benefit of workers in other parts of India. A statement showing the number of pure strains isolated follows immediately:

Crop				No. of strains isolated	Crop				No. of strains isolated
Wheat	..	..	..	105	Garden Pea	..	..	..	41
Barley	..	..	..	24	Field pea	..	..	..	30
Oats	..	..	..	..	Lentil	..	..	..	66
Rice	..	..	..	164	Linseed	..	..	..	124
Black gram	..	..	..	25	Safflower	..	..	..	34
Green gram	..	..	..	40	Sesamum	..	..	..	30
Pigeon pea	..	..	..	82	Hibiscus	..	..	..	13
Gram	..	..	..	84	Chillies	..	..	..	52
					Tobacco	..	..	..	60

Rice:

Considerable attention was paid to this crop as it is the most important food crop of the country. Nearly 1,200 samples of paddy were collected from all the rice-growing districts of Bihar and Orissa and out of these 123 distinct types were finally isolated, described and classified, in 1934. Later 157 paddy samples were collected from the Punjab and the Western U.P. and studied

at the Botanical Substation, Karnal. Forty-one types were finally isolated, described and classified in 1936 and were added to the previous collection, bringing it to a total of 164 N.P. types. Some of these were found to be high yielding and of good quality and were released for general cultivation. These types are:

Autumn paddy: N.P. 18, 97, 125, 130, 144.

Winter paddy: N.P. 24, 31, 52.

Deep water winter paddy: N. P. 9.

Wheat :

Wheat also received much attention at Pusa. In the beginning, the immediate objective was the development of high-yielding strains of good quality by selection and hybridization. The New strains evolved at Pusa immediately became popular and made their mark both at home and abroad. The Pusa* wheats, as they were called, were considered a notable achievement at that time because they appeared at a period when the reputation of Indian wheat was rather low in the export market and there was a general feeling that high quality wheats could perhaps not be produced in India. The actual fact, of course, is that our country is endowed with an amazingly rich variety of wheats and there were, therefore, immense possibilities of developing superior varieties suitable for different regions and for different needs. An extensive series of milling and baking tests with the strains evolved at Pusa were carried out by the Institute in co-operation with Dr. A. E. Humphries and Dr. E. A. Fisher in the U.K. ; these tests proved conclusively that many of the Pusa wheats possessed the desired character of free milling and also yielded flour and loaves of the same class as the North American spring wheats—the wheats which have been in the greatest demand in the United Kingdom for bread making and which have commanded the highest prices. In fact, Pusa 4 won several first prizes for grain quality in exhibitions held abroad. Pusa 4, Pusa 12 and Pusa 52 soon occupied very considerable area, at one time estimated to run into several million acres; they have continued to be popular and even now the area under these wheats is quite considerable. For instance, according to a report published in *Indian Farming* in March 1943, Pusa 52 has replaced local wheat to the extent of 80 per cent. in most of the wheat-growing areas of Bihar. Besides the three wheats mentioned other wheats were also evolved later. But space does not permit description of these. Mention should, however, be made of Pusa 120, which was outstandingly resistant to all the races of yellow rust occurring in India and of Pusa 165 distinguished for high yield, large grains of good quality, and a very useful measure of disease resistance.

• *Pigeon-pea (rahar) :*

From the all-India collection of pigeon-pea varieties, 82 types were isolated out of which seven were selected for distribution.

Studies on the serious wilt-disease of this crop carried out jointly with the Mycology Division showed that N. P. 80 was highly resistant to the disease while N. P. 16, 41, 50, 51 and 82 also possessed some resistance. Wilt resistance could not be correlated with the morphological characters studied; it also appeared that if a resistant variety was grown in a field which had been under *rahar* for three or more seasons it loses its resistance. This loss in resistance, however, was not transmitted to the next generation.

*Now known as N.P. or New Pusa Wheats.

Other crops :

Improved strains were also produced in barley, oats, linseed, sesamum, gram, lentils, hibiscus (for fibre), tobacco, chillies, etc. A list of the improved strains evolved during this period which have been under distribution in varying quantities is given below :

Wheat: N.P. 4, 12, 52, 80-5, 101, 111, 114, 120, 125 and 165.

Oats: N.P. 1, 2.

N.P. Hyb. 1, 2, 3 and x-27.

Barley: N.P. 13, 21 and 24.

Paddy: N.P. 9, 18, 24, 31, 52, 97, 125, 130 and 144.

Pigeon-pea: N.P. 15, 16, 24, 51, 64, 80 and 82.

Gram: N.P. 2, 6, 17, 25, 28, 53 and 58.

Mung: N.P. 18, 23, 28 and 36.

Urid: N.P. 4, 6, 7 and 14.

Lentil: N.P. 11 and N.P. Hybrid 1.

Peas: N.P. 29.

Linseed: N.P. 12, 121, 124 and N.P. Hybrids 10, 21, 55 and 68.

Sesamum: N.P. 3, 7 and 29.

Safflower: N.P. 1 and 30.

Chillies: N.P. 34, 41, 46A and 51.

Hibiscus: N.P. 3, 6 and N.P. sab. 5.

Tobacco (rustica): N.P. 18.

Tobacco (tabacum): N.P. 28, 58, 63, H. 142, H. 177.

The demand for seed has been especially heavy in respect of wheat, barley, oats, gram, pigeonpeas, peas, linseed and tobacco.

Indigo :

Investigations on the agricultural and botanical aspects of indigo which was at that time an important crop were undertaken in 1913 when the cultivation of Java indigo in Bihar had considerably fallen, largely on account of wilt disease and the difficulty of obtaining seed. Both these problems were worked out and the following results were obtained.

Wilt disease :

(i) Wilt disease was observed to occur generally in July and August as a result of which the plants lost vigour, growth, became slow, leaves fell off and the plants died, (ii) Wilt appeared soon after the first cut was taken and it was further observed that as a result of cutting back the plant, the roots and the nodules suffered extensive damage, and the wilt invariably appeared when regeneration of roots did not take place, (iii) the regeneration of the root system entirely depended upon good aeration of the soil and satisfactory drainage, (iv) Lysimeter experiments indicated that no wilt appeared if the drainage was normal and if there was no water logging.

Seed production :

(i) It was observed that the indigo crop of Bihar was much degenerated because the crop actually consisted of a number of types many of which were not suitable for Bihar conditions. (ii) The practice of leaving the plants to seed after the first cut generally resulted in a poor crop of low vigour which

gave a very low amount of seed; seed was, therefore, imported from Java every year and the imported seed was generally a mixture of types. (iii) As the crop was cross-fertilized it was difficult to maintain the purity of the crop. (iv) As a measure to obtain good seed it was suggested that the crop for seed should be sown in August on high-lying lands with good surface drainage, and surface cultivation should be regularly attended to. Such a crop would flower in November when weather was dry and warm and was suitable for fertilization and bees were also active during that period. A good quantity of seed generally resulted from such a crop.

Selections :

(i) It was observed that the deep-rooted types were particularly susceptible to wilt, while the shallow-rooted types did better. (ii) It was also observed that deep-rooted types were generally those which were late in maturity. (iii) Early flowering shallow-rooted types giving good growth were evolved by selection and types 10, 15 and 20 were found to be particularly suitable. The indigo work was closed in 1920.

Horticultural crops :

In the year 1905 a series of experiments on fruit trees were initiated at Pusa. Different varieties of citrus, plum, custard apple, loquat, peach, guava, litchi, mango, fig and banana were included in these studies. Experiments with oranges and peaches showed that the end of the cold weather, February was the best time to plant trees at Pusa. Trees so planted quickly established themselves and were able to withstand water-logging during the rainy season. An improved system of irrigation for fruit trees, the ring and furrow irrigation, was recommended. This consisted of digging a long trench parallel to a row of trees. Each tree is surrounded by a furrow ring and these rings are connected to the longitudinal trench by short transverse trenches. The results of experiments on tillage of fruit lands brought out the harmful effect of grassing down, that is, keeping the lands like lawns all through the year. Suggestions were made for the prevention of surface wash by a system of embanking combined with a leguminous cover during the rainy season.

Studies on fruit trees in Baluchistan were also conducted by the Howards. This work, started in the year 1912, was carried out at the Fruit Experiment Station, Quetta. It was found that the Mazzard or common cherry which was very popular as a stock for cherries in Europe and America was highly unsuitable for the conditions obtaining in Baluchistan, but another stock, Mahaleb, was very successful. Other stocks were also tested.

Other studies :

Genetical studies were conducted in wheat, barley, oats, linseed, safflower, sesamum, pigeonpea, gram, hibiscus, tobacco and chillies and the mode of inheritance of a large number of characters was worked out and published. But it is not possible to refer to the results here in detail. Physiological studies were also carried out although not on a very extensive scale; these included studies on the root systems of a number of crop plants.

The second period (1936-45).

This period was characterised by an enlargement of the work of the Division to include the application of the latest techniques of cytogenetics to plant breeding methods.

A small unit for plant physiological investigation was also added.

Wheat improvement :

Although the well-known Pusa wheats fulfilled a great need of the wheat grower, the problem of combining high yield and good quality with resistance to the major diseases still remained unsolved. The production of drought resistant strains for dry regions which constitute a greater part of the area under the crop had also to be tackled. Breeding for adaptability to particular regions such as different altitudes and special characters like well-standing straw and non-shattering of grains also needed attention. With these general objectives in view, work on the improvement of this crop was put on a broader basis and genes from diverse sources were being utilized for building up new strains and also for incorporation in the existing strains. A collection of wheats grown in different parts of India as well as many wild and cultivated species of wheat and allied plants from abroad was built up and has been under study with the object of utilizing the valuable stocks for wheat improvement. With this material a number of interspecific and intergeneric crosses were effected and their progenies were under selection.

The rust disease which is caused by three different kinds of rust—black, brown and yellow—is a serious menace to wheat production in the country. With the aid of a scheme financed by the Indian Council of Agricultural Research, considerable progress was made in breeding for rust resistance for the hill areas, in collaboration with Prof. K. C. Mehta of Agra University. By suitable hybridization between indigenous and exotic varieties, strains separately resistant to all races of the brown and yellow rusts known to occur in India were built up while hybrids resistant to black rust were in the stage of final tests.

Besides work on wheat rust, a large number of wheats, both Indian and foreign, were tested for resistance to loose smut and flag smut diseases, jointly with the Division of Mycology. It was established that a number of strains, including N.P. 114 and N.P. 120 were highly resistant to loose smut and N.P. 4, 80-5 and 111 were highly resistant to flag smut; N.P. 165 possessed some resistance to both the diseases.

High yielding potatoes :

Potato is an important crop of the country but it did not receive much attention in the early years. With the financial aid of the Indian Council of Agricultural Research, a substation of this Division was established at Simla for potato breeding in 1935. A study of over 500 samples of cultivated varieties collected from different parts of the country, which was begun just before the transfer of the Institute to New Delhi, was continued with a view to removing the confusion that prevailed in regard to varietal identification and nomenclature. Twenty-eight distinct varieties were found to be under cultivation in India and only seven of commercial importance. A bulletin describing the results is in the press. Simultaneously, an extensive collection of the tuber-bearing species of *Solanum* from South America (both wild and cultivated) and varieties of potato from foreign countries was also under study for evaluation from the point of view breeding potentiality. As a result of crosses between foreign and Indian varieties, a number of hybrids were evolved at Simla and were under trials in the hills. These hybrids were found to do well particularly in the U.P., West Bengal and the East Punjab. Trials of hybrids suitable for the plains in India was likewise taken up during this period and preliminary selections were made at Delhi

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and Pusa. A beginning was also made during this period to build up disease-resistant potatoes by utilizing the South American species which are immune to some of the diseases of the crop, especially late blight.

At the Potato Breeding Substation, Simla a method was developed in which sprouts arising from the seed tubers were successfully used for planting.

Tobacco improvement :

Work on this crop was conducted at the main Division at New Delhi, the Botanical Substation at Pusa and the Tobacco Research Substation at Guntur: the latter has now been taken over by the Central Tobacco Committee. A large collection of indigenous and exotic varieties was built up and studied. Among the important results achieved in this crop was the selection of a new type of cigarette tobacco, Amarelo 5, from an introduced variety. In regard to the time taken for curing and high percentage of first grade yellow leaf, the new type of tobacco was found to be better than Harrison's Special, the variety which had previously been considered to be most suitable for flue-curing in India. A new type of chewing tobacco, N.P. 70, was released for distribution.

Breeding work was initiated to evolve types of tobacco with high nicotine content which would be useful for commercial preparation of nicotine sulphate as an insecticide.

It was shown by experimental evidence that contrary to a popular belief, Indian-grown seed of Virginia-type varieties could be used for sowing year after year without deterioration in the quality of the leaf provided the seed was kept pure.

Disease-resistant linseed :

The earlier investigations on linseed resulted in the evolution of strains that were high yielding with satisfactory oil-content. The problem of the rust disease however remained unsolved as all the indigenous types available were susceptible. Crosses were therefore made between the best of the latter and immune types obtained from Australia; the latter were too late in maturity to be suitable for direct cultivation. The hybrid progenies were studied at Delhi and also at the Sub-stations at Pusa and Karnal, under conditions of natural infection. In this way about 200 apparently immune types were obtained.

In 1942-43, testing under controlled conditions with the races of linseed rust found in India was taken up in collaboration with Dr. Prasada of the Rust Research Laboratory, Simla. These tests indicated that a large number of the new strains were immune.

Wilt-resistant pigeon-peas (rahar) :

Joint investigations during the first period by the Divisions of Mycology and Botany had resulted in the discovery of several types highly resistant to the serious wilt disease of this important pulse. Unfortunately these types were not of good eating quality and hence crosses were made in 1927-28 and 1935-36 to unite the good qualities of strains like N.P. 5 and 51 with the wilt resistance of N.P. 24 and 80. The cross progenies were at first studied only under infected field conditions at Pusa; later from 1941-42 they have been tested under controlled conditions in the laboratory also with the cooperation of the Division of Mycology. Several promising types possessing a higher degree of wilt resistance, with desirable agronomic characters have now reached the trial stage.

Utilization of wild species :

As a result of earlier work, three strains of sesamum, N.P. 3, 7 and 29 (the first two, white-seed, and the third black-seeded) had been under distribution. Investigations were now taken up to evolve disease-resistant *Sesamum* by hybridizing cultivated varieties with a wild species, *Sesamum prostratum*, which is reported to be immune to important diseases of this crop. Breeding work was initiated for the development of new strains of tomato with early maturity, good flavour and high vitamin C content by hybridizing the cultivated forms with a wild species of tomato.

Polyploidy as a method of crop improvement :

It is now established that some cultivated plants have evolved in nature as a result of the duplication of some or all the chromosomes of the basic set characteristic of a given species. With the aid of an alkaloid, colchicine, similar changes can be induced artificially in crop plants. When the full set of chromosomes is doubled, the resulting plants, called tetraploids, usually show increase in the size of their parts like branches, leaves, flowers, seeds, etc. With a view to utilizing increased plant size in crop improvement, tetraploids were experimentally produced at New Delhi in a number of crop plants including chilli, gram, *Sesamum*, *rai*, *toria*, *sarson* and *taramira*. Increase in seed size was associated with low fertility and consequent reduction in yield in the tetraploid plants. Selection in the progenies of crosses between different tetraploids have indicated the possibility of developing polyploids with increased fertility, especially in crossed fertilised crops like the *Brassicaceae*.

Synthesis of cultivated species in the laboratory :

Cytogenetical studies have shown that the origin of new plants in nature was sometimes brought about by hybridization between different species followed by duplication of chromosomes. Experiments conducted in this Division have clearly demonstrated this process. An oil-bearing plant, *rai*, (*Brassica juncea*) was actually synthesized in the laboratory by crossing two species, *B. campestris* and *B. nigra*. The resulting hybrid which was sterile was rendered fertile by colchicine treatment. The fertile hybrid thus produced artificially is apparently the same as *B. juncea* which occurs in nature.

Genetical investigations :

These included the identification and study of the mode of inheritance of a number of mutations like variegation in rice and wheat; chlorophyll deficiency in chilli, linseed and safflower; tiny leaf, simple leaf, narrow-leaf and narrow-leaf-sterile mutants in gram; apetalous and closed petal mutants in *toria* (*B. campestris*); bunch mutant in chilli and mutant in linseed which showed a floral abnormality. The genetics of self sterility in some diploid species of tuber-bearing *Solanum* was studied and the inheritance of sex forms in *Luffa* was worked out.

Study of hybrid vigour :

The object of this study was the commercial exploitation of heterosis in crop plants. Marked hybrid vigour was observed in tobacco and brinjal. The brinjal cross, Muktakeshi and clustered white was found suitable for utilising hybrid vigour on a commercial scale, and seeds have been supplied to those interested. The results of earlier experiments had demonstrated the desirability of studying the phenomenon under a wide range of environmental conditions.

The problems of low seed setting in berseem :

Seed setting in this important fodder crop is rather low at Pusa compared to Delhi and places further west. Investigations into its cause revealed that inadequate numbers of bees at flowering time, which are the principal agents of pollination in the crop, was mainly responsible for the meagre setting of seeds at Pusa.

Cryptostegia investigations :

The situation arising out of the world war II necessitated investigations on the possibility of developing new sources of rubber in place of the *Havea* rubber. *Cryptostegia grandiflora* was considered that time to be a possible source for obtaining rubber during the emergency, and a series of experiments on methods of propagation, growth and the productive capacity of the plant in terms of latex was carried out.

Physiological investigations :

Experiments on vernalisation were started at New Delhi in 1938 and the results obtained are summarised below :

English and exotic winter wheats which are normally too late for Delhi conditions and produce only shrivelled grain or none at all, when subjected to low-temperature treatment in the early stage and long day treatment later flowered and matured earlier at the same time as some of the local wheats. Unlike the English winter wheats even the unvernallized plants of Indian wheats reacted to long day treatment, and flowered much earlier.

In collaborative trials with Mr. Boshi Sen of Almora, the response of Indian varieties to vernalization was tested and it was found that out of 150 varieties treated about 40 flowered earlier, the earliness ranging from one to three weeks. These varieties mostly included wheats from the Punjab, Kashmir and Baluchistan. The varieties, which under Delhi conditions develop only shrivelled seeds, were able to form, as a result of vernalization, good seeds but even after the treatment they yielded less than the early varieties already in cultivation.

Experiments were also conducted to see the effect of vernalization on other crop plants, viz. gram, linseed, chilli, soybean, tobacco and potato but although earliness could be induced, especially in gram, the results did not show any promise of practical application.

Drought resistance :

A comparative study of 260 exotic and Indian varieties of wheat with and without irrigation was conducted over five seasons.

It was shown that suitability of varieties of wheat for different localities could be judged on the basis of the length of their vegetative period so that conditions of drought prevalent during the ripening of grain could be avoided. For instance, varieties with very short vegetative periods would suit the C.P. region where the growth period was very short, whereas varieties with longer vegetative period would suit regions north of Delhi better because the temperature during March would be quite favourable for grain filling.

The present period (1945-48).

This period was marked by an expansion of research and training activities. The Division was reorganised into the sections of Genetics and Plant Breeding, Cytogenetics and Cytology, Crop Physiology and Plant Introduction. The last named is still only a nucleus but work has been in progress with the aid of a small grant from the Indian Council of Agricultural Research for plant introduction. Work on cytogenetical aspects of hybrid maize was also taken up under another scheme financed by the Indian Council of Agricultural Research. A resume of some of the more important researches conducted during this period is given below.

Breeding for rust resistance in wheat :

During the present period, wheat hybrids resistant to the physiologic races of the black rust were "fixed" in addition to the brown and yellow rust resistant strains already on hand. To test the possibility of using these wheats for immediate cultivation in the hills, they were put under small-scale yield trials in several places in that region. Many of the strains were found to retain their resistance to the particular rust against which they were bred. Those resistant to yellow and brown rust, however, showed susceptibility to black rust. The strains resistant to black rust appear to possess some resistance to other rusts also and are being tried out at a number of centres in the hills.

A double cross was made on a large scale to combine high resistance to the three rusts with desirable agronomic characters. Among the progeny of this cross, a number of plants showed only a trace of one or two rusts and appeared to be promising in other characters also. By judicious selection, superior strains resistant to rust are expected to result from this cross.

New N.P. wheats :

A number of new strains of hybrid origin evolved at the Division were under trial at different stations. These trials were conducted in order to learn the suitability of the new N.P. wheats for the important wheat-growing tracts in India. Some of them have given good results for the past few years at a number of centres. Some of them have also shown a useful degree of rust resistance or rust tolerance, especially to brown rust. Amongst the most promising of these new strains are: N.P. 710, N.P. 715, N.P. 718, N.P. 737, N.P. 745, and N.P. 760, N.P. 761 and N.P. 775.

Varietal-cum-manurial trial in wheat :

Different varieties respond differently to manurial treatment; some give excellent yields on well-manured lands but cannot thrive on poor soils while others are capable of giving fairly high yields under conditions of low fertility. Information regarding the response to manuring of the material on hand is essential to the plant breeder so that he would be better able to recommend existing varieties best suited for different regions and to develop new varieties, if necessary, for special areas. An experiment was laid out at the suggestion of the Director to test the interaction between varieties and different levels of manuring, using some of the wheats which are already under distribution as well as those that have recently been evolved at this Division. This is still in progress.

Potato improvement :

Hybrids suitable for the plains were bred and trials at a few centres in the main potato-growing tracts in the plains of India were initiated in the post

war period. Hybrids No. 45, 208, 209, and 610 gave encouraging results in Bihar, U.P., and East Punjab. The importance of proper manuring to obtain high yields, particularly from the hybrids, was brought out by experiments conducted in Agronomy Division. Trials in the hills were continued and hybrids 9 and 12 reached the multiplication stage in the U.P., and 5 and 9 in West Bengal, having given a good performance for a number of years.

Considerable attention was paid during this period to the problem of disease resistance in potato. As a result of work on fungus diseases, hybrids resistant to late blight, a fungus disease which occurs mainly in the hills, were built up by utilizing the immunity of a wild South American species, *Solanum demissum*. These hybrids are now in the stage of field trials. Recently, a considerable amount of potato material was obtained from Cambridge and is being utilized for breeding work.

Rust resistant linseed :

Breeding for resistance to rust in this crop was continued and testing work carried in cooperation with the Division of Mycology. One hundred and one strains of hybrid origin were tested for their resistance to rust both in the seedling and adult stages. Under conditions of an artificial epidemic, 70 strains were completely free from the disease. The Indian parental varieties, on the other hand, were heavily infected. Under conditions of natural infection in the field, only four of the 101 strains showed rust attack.

Preliminary trials with 35 of these promising strains showed that in C.P., East Punjab and West Bengal the new N.P. strains were free from rust attack while the best local variety used as control in each area was infected. In West Bengal and East Punjab many of the rust resistant strains outyielded the control. According to the "Report on oilseed crops in India" by Mr. C.M. John, Officer on Special Duty with the Indian Oilseeds Committee, two of the new rust-resistant strains No. 10 and No. 37, out-yielded Kangra Local at Kangra to the extent of 50 to 125 per cent. More systematic trials have now been planned to facilitate final selections of rust resistant strains for various regions. A large number of these strains also possess very high oil content according to the analyses carried out in the Division of Chemistry.

Early varieties of tomato with improved flavour and high vitamin content :

Commercial supplies of tomato are usually not available earlier than the middle of November in the plains of northern India. By the time the crop starts yielding a good harvest, it is liable to be damaged by frost. The need for evolving early varieties which can give appreciable yields before the frost appears is therefore obvious. A study of the available collection of genetic stocks of tomato revealed that the South American wild species, *Lycopersicon pimpinellifolium*, which had already been used in the U.S.A. and Germany for producing early varieties of tomato, was a promising material worth utilizing in this project.

By judicious selection of early maturing plants in the progenies of crosses with this wild species it was possible to isolate types which were earlier than either parent. A few small-fruited types with higher vitamin and sugar contents have been selected. These strains are also capable of giving early crops if they are planted, i.e., in August. Arrangements have been made to send some of these promising selections for trials in the provinces.

A collection of useful genetic stocks comprising closely related wild species and different varieties of tomato was imported and their breeding possibilities are under study.

Hybrid maize :

It is common knowledge that the resulting progeny of a cross between two parents is sometimes more vigorous than either parent. This phenomenon is known as hybrid vigour. The possibility of utilizing hybrid vigour in the production of maize was first suggested in the early years of this century but it was only in the middle thirties that it became commercially successful. It is estimated that at the present time about 80 per cent of the total area under maize in the U.S.A. is planted to hybrid maize. The yield increases obtained thereby are reported to be 20 to 30 per cent over the open-pollinated varieties that had been in use prior to the introduction of hybrid maize. This revolutionary change in American agriculture was brought about by the systematic and well-planned work of experienced plant breeders in the U.S.A.

Under a scheme financed by the Indian Council of Agricultural Research, work has recently been started in this Division to produce hybrid maize in India. As the final success largely depends on the number of inbreds available for different hybrid combinations, extensive collection of indigenous and exotic varieties was made and the isolation of desirable inbreds from them was under way. A number of double crosses received from Australia and the U.S.A. have been sent for trials in the provinces to see if any of them would be suitable for direct cultivation in India. Investigation of certain important problems like the comparative merits of selfing and sibbing, extent of homozygosity necessary before inbreds are crossed, convergent improvement and polyploidy have also been undertaken.

Polyploidy as a method of crop improvement :

Polyploids in chillies, gram, toria and sarson were under study and it was found that such plants had generally reduced fertility. Selection for fertility was not successful in all these crops except in toria which is a cross pollinated crop.

During the period, polyploid forms of a number of new varieties of chillies, gram and toria were obtained. To induce greater variability for getting the proper material for selection hybridization between inter varietal tetraploids have been made and the work is in progress. Some promising tetraploid selections have been made for trial in toria. Recently, polyploids in linseed have also been taken up for study. It is now generally accepted that in no case the new auto-tetraploids have been of value for direct cultivation. It has been found, however, that these auto-tetraploids could be improved by judicious breeding, using a large and varying genetic material. Cytological studies of these tetraploids here have indicated the basis of the true breeding nature of these induced tetraploids. In *Eruca* it was, however, found that due to meiotic irregularities it could never breed true.

Inducing polyploidy in an interspecific hybrid between *Sesamum orientale* x *S. prostratum* (a wild species) undertaken for the purpose of evolving strains resistant to phyllody disease has given rise to a fertile amphidiploid. This plant was, however, not found to be suitable for direct cultivation and methods of back crossing of this amphidiploid to the cultivated parent were taken up. A number of promising selections from the progeny of the back crosses were obtained which are now under trial. A number of trisomics (i.e. cultivated *S. orientale* with an extra chromosome of the wild parent) have been isolated

and are under study for getting desired characters transferred to the cultivated parent.

Other lines of cyto-genetical investigations :

Additional lines of cytogenetical research have been initiated very recently for the study of interspecific and inter-generic hybrids of wheat and related species and genera and also the investigation of techniques for a fundamental study of the structure and composition of chromosomes.

Plant introduction :

With the expansion of the activities of the Botany Division a nucleus scheme, called the Plant Introduction Scheme, was started in 1946. The main purpose of this scheme is to utilise the improved strains of cultivated crops, vegetables and fruits of other countries either for direct cultivation or for use as stocks for breeding work in our country. Collection of wild relatives of crops and useful plants other than those that are now under cultivation is also one of the activities of the Plant Introduction Scheme.

The plant introduction scheme at this Division has just completed three years of work. During this period as many as 1500 samples of seeds have been received from overseas for trial in India. These seeds are received in most cases on an exchange basis. Nearly 300 varieties of maize, 50 varieties of sweet potato and 13 of tapioca are now growing in the experimental plots of the Division. Many of the promising varieties have been or are being distributed to the Indian provinces and states unions for trial and multiplication. Particular mention may be made of a variety of cowpea (*Vigna sinensis*) from the Philippines which is very quick-growing and yields good pods within six or seven weeks from sowing. Included in the collections at this Division are a perennial plant, *Lespedeza*, and Bahia grass which are very useful for soil conservation.

The present scheme of plant introduction at this Division is working with a small annual grant from the Indian Council of Agricultural Research. At the time of implementing the scheme, the Indian Council of Agricultural Research recognized the great importance of the work and hoped that before 1951, the scheme would be expanded by the Government and would become a permanent feature of the work of the Indian Agricultural Research Institute. Accordingly a scheme for the establishment of a permanent bureau of plant introduction was submitted to the Government of India. The original scheme has since been revised to suit the present economic conditions and is under their consideration.

Drought resistance :

One of the major factors limiting crop production in unirrigated tracts is drought. Nearly three quarters of the area under wheat, or perhaps more, is unirrigated and the success of the crop in these tracts would seem to depend largely on the moisture accumulated in the soil during the previous monsoon. It is, therefore, necessary to have varieties which tolerate drought and yield reasonably well. The problem of evolving drought resistant varieties is however by no means simple as can be illustrated from the fact that varieties that give high yields under irrigation may not necessarily keep up the same superior performance under unirrigated condition.

The plant breeder is concerned with combining as many desirable attributes as possible in the new strains that he produces and one of these is the ability to tolerate drought. In spite of extensive investigations carried out in

different parts of the world over several decades definite knowledge regarding the distinguishing characters associated with drought resistance is not available. This knowledge would enable the plant breeder to isolate such plants without taking recourse to arduous and time-consuming methods necessarily involved in performance tests. The investigations undertaken in the physiology section aim at elucidating the relationship between developmental characters and drought tolerance.

Experiments undertaken over two seasons indicate that varieties that do not yield well under deficient soil moisture either do not produce sufficient number of ears or form fewer grains per ear. This observation, however, requires to be confirmed over several seasons and in several localities before accepting it finally as correct. It also remains to ascertain further whether any characters, correlated with drought tolerance, can be identified in the seedling stage.

Physiological analysis of yield :

Yield is the net result of the various physiological processes of the plant and it is, therefore, of great scientific as well practical interest to know which of these processes are in the direct line of yield. In fact, the problem of drought resistance is but one aspect of the problem of yield. Under varying environmental conditions the performance of different strains or varieties is not constant and it is important to ascertain the underlying causes. The problem may be stated thus : what are the processes that are influenced by the environment as a result of which variations in yield are brought about? This knowledge would be useful in judging the suitability of varieties or strains for different localities and in breeding accordingly. Preliminary work in this direction indicates that the contribution of dry matter from the leaf, stem and ear to grains (in wheat) differs with varieties and that varieties in which the ear contributes relatively more to grain weight may yield relatively better under certain adverse conditions.

Studies on the effect of light and temperature :

Light and temperature are two very important conditions that have profound influence on plant growth. By suitable adjustments in the levels of these factors it is possible to control the time of earing (flowering) and trials are now under way to raise three generations of wheat within a year with a view to hastening the breeding programme.

Physiological aspects of plant nutrition :

For efficient utilization of land it would seem obviously desirable to grow and breed varieties suited to different fertility levels. Reference has been made earlier to a varietal-cum-manurial experiment for studying the response of different wheat varieties to different levels of manuring. There is evidence that varieties differ in their optimum requirements of nutrition. For instance, variety 'A' may yield higher than variety 'B' and yet the former may absorb as much nutrients from the soil as, or even less than, variety 'B'. The question naturally arises about the nature of the processes that are concerned with differential utilization of nutrients by varieties. Information on this question can be expected to assist ultimately in breeding varieties for this purpose. Studies in these lines have been undertaken only recently and it would be premature to make any definite statement just at present.

Studies on plant hormones are also in progress.

DIVISION OF SUGARCANE BREEDING STATION AT COIMBATORE

Introduction

Since Capt. Dick imported thick type of canes from Mauritius in 1927, numerous imported exotic tropical canes known as the introduced canes were obtained and tried. Farmers seemed to favour the poor yielding indigenous canes because of their hardy nature and their comparative tolerance to diseases while the introduced canes though found to give phenomenal yields in comparison with the former in the first few years of cultivation, had to be given up later due to their heavy susceptibility to diseases. Some of these introduced canes as "Thana" and "Shamshara" are however quite good and are still in cultivation in Bengal.

The simultaneous discovery of viable seed in sugarcane in 1888 by Soltwedal in Java and Harrison and Bovell in Barbados laid the foundations for breeding sugarcane. An impetus for research was provided by the 'sereh' epidemic in Java. The tropical canes and their hybrids did not prove useful. The expedition of Dr. Kobus to British India led to the selection of a northern Indian cane *Chunnee* for hybridization, and seedlings combining resistance and yield were obtained in Java. In India the dependence on the white sugar from Java led to the establishment of a cane breeding station at Coimbatore, where the canes flower more easily. Cane breeding work was started there in 1912 by Dr. Barber as the Sugarcane Expert, acting under immediate control of the provincial government.

*The first period (1912-1936).**Breeding co. canes :*

The problem had been mainly to replace the poor-types of canes by better types so that the average yield of cane can be increased.

A wide range of parents had been employed at Coimbatore in its breeding programme. It was the first sugarcane station to deliberately employ *S. spontaneum* and to raise an intergenetic hybrid with sugarcane (*Saccharum* × *Narenga*). Certain of the popular Coimbatore canes include in their parentage three different species of *Saccharum*. During the period 1912-1918 the Coimbatore canes, Co. 205, Co. 210, Co. 213 and Co. 214 were bred and released for cultivation. These canes later replaced the indigenous varieties throughout North India and came to form (particularly Co. 213) the backbone of the Indian sugar industry.

Morphological studies :

The first attempt at classification of the canes was made by Barber on the basis of broad vegetative characters relying mainly on those of root, stem, leaf and general habit and the results were published in the form of memoirs. His recognition of five distinct groups in Northern Indian canes, which have been later found by Bremmer more or less to agree with different chromosome groups, is a sufficient testimony to his methods of analysis and his judgement, specially considering the limited nature of characters selected by him.

Intergeneric hybridization :

Mr. T. S. Venkataraman (later Sir) who was already associated with Dr. Barber as his assistant and colleague succeeded the latter as Sugarcane Expert in 1919-20 and the Sugarcane Breeding Station became a part of the

Indian Agricultural Research Institute with the transfer from provincial to central control from 1st April, 1925.

The range of parents employed in hybridization was extended to other genera like *Sorghum* and *Bambusa*. Important studies were undertaken on the improvement of technique of breeding, the development of the root system, estimation of rind hardness and collection and assessment of *S. spontaneum* types from Bihar and Assam. A system of artificial rooting of canes was evolved which enabled the isolation of desired parent canes for carrying out controlled hybridisation work on a mass scale. The development and character of 'sett' and 'shoot' roots, and the location of the live regions of the root system, have been studied with very beneficial results to the study of the crop as a whole.

The Co. canes evolved at Coimbatore during this period gradually replaced the earlier Co. canes under cultivation and the greater area, part of the sugarcane area came under the cultivation of these canes; the sugar industry in Northern India was specially benefited. Co. 285 replaced Co. 205 and Co. 313 and 214 gave place gradually to Co. 312 and Co. 313. Co. 281 though not a successful cane in India was found to be a very useful cane in South Africa. Other important canes released during this period were Co. 331, 370, 395 and 527.

The wild Saccharums :

A beginning was made with collections of *S. spontaneum* and 20 types collected including those from Java, Burma, Mauritius and New Guinea. A variety of *S. robustum* was also obtained.

Cyto-genetical studies :

It would appear probable that the primitive forms of *S. spontaneum* are those with a relatively low number of chromosomes and certain of these forms occur in India. Interspecific crosses were studied and controlled crosses made for obtaining reliable material for cytogenetical work in the genus *Saccharum*. The necessary artificial emasculation presented considerable difficulties on account of the smallness of the flowers, but the work has yielded a certain amount of material. The reciprocal crosses with *Sorghum* as female parent proved unsuccessful.

Other studies :

In 1928 the breeding of thick canes was begun. They are more suitable for tropical India. Studies on the viability of sugarcane pollen, period taken for fertilisation and photoperiodism were also initiated.

The Second period (1936-1945).

Commercial Co. canes :

During this period the work on the breeding of thick canes yielded definite practical results. A varietal survey conducted in the year 1942 indicated that Co. 419 had come to occupy 50 per cent. of the area in the Deccan Canal tract of Bombay and about 40 per cent. of the area in the Vizagapatam and Godavari tracts in Madras Province. Co. 421 occupied 7 per cent. of the areas in western United Provinces, 10 per cent. in Central United Provinces and 8 per cent. in eastern United Provinces.

Pith studies :

Pith studies have shown that the two pithy canes Co. 349 and POJ 2878 yielded seedlings which were usually pithy and when these are used as parents one should be prepared for a considerable amount of pith in the progeny. Co. 213, Co. 281 and Co. 508 have a solid core and transmit this character to the progeny. The above results indicate the transmitting qualities of the five parents when used as female parents. In the course of these studies it was noticed that whenever Co. 244 and Co. 301 were the male parents, they contributed to the solid core of the seedlings.

Studies on Pollen :

A method of studying the viability of pollen by culturing it artificially had already been evolved at this station and was available for assessing the viability of stored pollen. Pollen has been successfully stored in thermos flasks with a view to enabling its transport to distances as great as 1,700 miles. Pollen maintains its capacity for germination up to one month. Investigations on the fertilising capacity of sugarcane pollen showed that *S. spontaneum* maintains its fertilising capacity up to four days indicating that if sugarcane pollen has to be transported long distance it should be done only by air.

Anatomical studies :

Attention was paid to the study and the inheritance of anatomical characters likely to be useful in the resistance of varieties to pests and adverse climatic conditions. *S. spontaneum* employed as a male parent has been found to transmit rind hardness to the hybrids.

Physiological studies :

Photoperiodism experiments for inducing flowering in non-flowering varieties and for hastening and delaying the reproductive phase in certain sugarcane used as parents have shown that some varieties such as *S. spontaneum* Burma which do not flower at Coimbatore, do so if the daily photoperiod is considerably reduced for about eight weeks before commencement of the flowering season. Similarly some other varieties e.g., Co. 421, POJ 2725 and *S. spontaneum* (Tabongo) which flower very early in the season have been made to flower late by about two months by increasing the day length at suitable stages in the life of the plant. By withholding the normal manurial treatments and increasing the water supply, it has been possible to induce flowering in Red Mauritius, 'Baroukha 134' and 'Sewari' which seldom flower at Coimbatore and to considerably hasten the time of flowering in others.

Cytogenetical studies :

It has been found that there is polyploidy within the species *S. spontaneum* accompanied with systematic differences, though a few uneuploid forms also are present. Among the Indian and the East Indian forms, the chromosome numbers indicate that forms with smaller numbers are found in North and North-west regions of India and that the geographical trend of distribution is from North-West to South-West in respect of higher polyploid forms.

Cytological studies on the megasporogenesis of Co. 421 to investigate the origin of the production of gametes with unexpected number of chromosomes indicated regularities both in the first and second divisions of meiosis while the corresponding divisions in the microsporogenesis were quite regular. The possibility of the formation of gametes with chromosome numbers lesser than the haploid number is indicated.

Studies financed by the Indian Council of Agricultural Research : and later by the Indian Central Sugarcane Committee :

Part of the work done at the Sugarcane Breeding Station was financed initially by the I.C.A.R. and later, after 1944, by the I.C.S.C. This relates to (i) the studies on the maintenance of a live herbarium at Karnal commenced in the year 1931, (ii) studies on the cytology and genetics of cane commenced in 1934 and closed in 1944 with the work having been incorporated in the general programme of the station, (iii) studies on the physiology of flowering of canes started in 1942 and (iv) survey and collection of *saccharum spontaneum* and related genera commenced in 1946.

The present period (1945-1948).

Breeding :

The various stages in sugarcane breeding are now systematised but further improvements have been found to be necessary for introducing greater precision. In the mass production of sugarcane seedlings from seeds considerations of cheapness led to the employment of earthenware pans on bamboo platforms leading to uneven supply of moisture and bad germination with the consequence of possible loss of valuable genetic material. Small-scale experiments with glass and uniform pottery left on a level platform showed marked improvement in germination. Provision was made on up-to-date lines for equipment for the germination of seedlings.

Breeding for disease resistance :

While the technique of sugarcane improvement in other countries was based on breeding for resistance to disease, in India on the other hand attention was diverted to replace the poor yielding Northern Indian cane by better yielding cane varieties. The history of the progress of cane breeding in countries like Barbados, Queensland and U.S.A. was one of gradual development of a system of technique which eliminated to a great extent the selection of seedlings which later might become very dangerous and thus provided security against serious disease epidemics similar to those which had occurred from time to time in the sugar industry of the past. In the breeding programme followed at Coimbatore and the varietal trials of the provincial stations systematic tests for the selection of cane resistant to diseases have not been done so far. The want of such tests led to the complete and sudden break-down of the important and popular cane Co. 213 due to red-rot epidemic of 1936, reminding us of similar epidemics in other countries prior to 1900.

Tests for diseases in the initial stages of selection before the improved varieties are released for yield tests in Provincial Research Stations have now been introduced in the breeding programme at Coimbatore.

The Co. cane varieties of which Co. 213, Co. 301, and Co. 331 are the parents are being studied for their resistance to red-rot, (*Collectotrichum falcatum* Wont.) by artificial inoculation of a virulent strain, and to smut, by dipping the setts before planting in smut spore suspension, in collaboration with the Division of Mycology. Simultaneously with the inoculation of the standing canes in the field, inoculations have also been made on cut canes. This method of inoculating the cut canes has been tried on 90 forms of *S. spontaneum*, collected during the course of the work of the Spontaneum Expedition Scheme.

Saccharum spontaneum Expedition :

Both in Java and in India only two forms of *Saccharum spontaneum* have hitherto been employed in cane breeding. These forms have introduced the quality of hardness and to some extent resistance to particular diseases in cultivated canes. Red rot and smut are two very important diseases to be reckoned with and it is highly probable that among the numerous forms of *spontaneums* available in the country, some might possess the quality of resistance to those diseases. Realising the importance of *spontaneum* in cane breeding, a scheme for the survey and collection of the *spontaneums* and related grasses was undertaken by the Indian Agricultural Research Institute with funds provided by the Indian Central Sugarcane Committee. Already 130 collections from South India have been made and other portions of the country are being surveyed. Among the collections these are types adapted to high altitudes upto 6,000 feet, water-logging and resistance to drought and salt. High altitude collections up to about 6,000 feet especially from the eastern ranges of Himalayas are frost resistant. These types are expected to be of great use in the breeding of cane adapted to these conditions. The assessment of these collections for resistance to important diseases and to drought and frost will have to be taken up and hybridization work planned suitably.

Selection and yield tests :

It would be pertinent to review the position of sugarcane research and indicate the possible lines of further improvement. Nearly more than 500 Co. canes had been sent out so far, but it is found that only 8 to 10 especially of the earlier releases are in general cultivation. This shows that selection at Coimbatore on the basis of increase in yield over that of the control (some of the existing Co. canes in general cultivation) has not proved effective.

Breeding work is mainly restricted to Coimbatore in view of favourable climatic conditions in relation to sugarcane flowering and seedling. But the rigorous selection of suitable varieties at Coimbatore for the totally varying soil and climatic conditions obtaining elsewhere in Northern India is not an ideal procedure if not incorrect one. The *ad hoc* Committee of which the Director of this Institute was the Chairman met on 3rd and 4th August, 1947 at Coimbatore and recommended that a large number of selections up to 200 should be sent for provincial research stations for trials instead of 8 or 10 as were sent previously. If the principle of providing suitable varieties for the different sugarcane tracts is kept in mind the ideal would be to reject obviously poor canes and restrict selection on the basis of the most stable characters such as habit, girth of cane, sucrose percentage, resistance to disease, absence of pith, good buds, self stripping, non-cracking of canes, non or sparse-flowering etc. Tests for yield should be left to Provincial Research Stations for the selection of suitable varieties for the respective tracts. At present more than fifty canes are sent every year to the Provincial research stations. Experiments have also been undertaken for selecting seedlings under different levels of manuring and irrigation.

Extension of trials in factory farms :

Till now the varieties from Coimbatore were being sent only to Provincial sugarcane research stations, and selected canes on the basis of yield tests at those stations were supplied to factory farms for cultivation. Some of the big factories in U.P., Bombay and Madras have ample facilities for carrying out trials and in fact do conduct trials with canes released for cultivation and maintain useful data. The importance of factory farms cannot be overlooked as centres of trials especially in view of accumulating evidence that

varieties respond differently even under different manurial and cultural treatment. The Board of Agricultural at the 7th meeting of Crops and Soils Wing held at Madras during April, 1948 realising the importance of the problem drew attention in one of its resolutions to the fact that the variety has to be fitted not only to the different regions distinguished by climate and soil type but also to different agricultural conditions based on water requirements and soil fertility. The tests at the factory would therefore be useful as additional trials and add to the value of the data obtained as Provincial Sugarcane stations for the fitting up of varieties. In view of the importance of the problem and the eagerness evinced by factory farms for close cooperation, canes are supplied to factory farms with the knowledge of the respective Directors of Agriculture.

Exchange of varieties :

Another reason which may have checked further advances is perhaps due to the fact that the amount of variability in cane has not been fully exploited. In any well organised breeding programme, periodical collection of plant material from countries where similar work is done is essential for continued progress. While the sugarcane-growing countries like Barbados, Mauritius and U.S.A. had obtained from Coimbatore nearly more than 131 varieties during the past 20 years the Coimbatore station on other hand added to the already existing initial collections only 25 varieties from outside countries. The necessity of getting useful and successful canes for direct introduction as also for use in breeding from the advanced sugarcane-growing countries is now realised and efforts are being made to get them by correspondence on an exchange basis.

There is a ban on importing into India useful cane material from cane-growing countries like Philippines, Australia and Queensland due to the prevalence of the "figi" disease in these countries. However, the U.S.A. is obtaining useful material from these countries without any untoward results by taking necessary precautions. With such precautions it should be possible for us to get useful cane material from these countries. The question of lifting the ban has been taken up with the Government of India.

Commercial Co. canes :

Co. 419 has registered a further advance in that it now occupies 70 per cent. of the area in the Bombay, Deccan, and in Madras also it has come to occupy 70 per cent of the area. Co. 421 has also registered an advance and is now one of the main varieties in certain parts of United Provinces. According to the figures now available, it occupies slightly over 200,000 acres in United Provinces. A cane which has recently come up is Co. 453. It is getting popular in United Provinces where it now occupies some 70,000 acres and in South Bihar it is now one of the main varieties. Two other canes deserve mention, i.e. Co. 513 in Bihar and Co. 527 in West Bengal, North Vizagapatam tract of Madras and in certain parts of United Provinces where it occupies 15,000 acres. Among the recent canes of promise Co. 475 and Co. 617 may be mentioned.

Inter-generic crosses :

No favourable reports have been received of the three "sugarcane $\times$ bamboo" seedlings released to the Provincial Stations in 1942. It has been found necessary to repeat the Sugarcane $\times$ bamboo cross but the seedlings now obtained look so much like sugarcane that it is doubtful if the cross has been genuinely effected. Their cytology, however, remains to be studied. In inter-generic crosses care has to be taken first to ascertain whether the seedlings in

question are parthenogenetic in origin before pronouncing them genuine inter-generic hybrids. This caution is also necessary in case of inter-generic crosses with certain grasses made with a view to evolve fodder canes by hybridisation.

Pith Studies :

Co. 301 and Co. 508 have been definitely found useful in introducing solid texture to the progeny and have been increasingly used in the breeding programme. Another cane added to this list is Co. 244.

Taxonomic studies :

As a result of morphological studies made, the 18 forms of *Erianthus* in the collection at the station have been found to possess specific characters in contradistinction to *Saccharum*. *Erianthus* should therefore continue to form a separate genus from *Saccharum*. In the genus *Erianthus* itself, three groups are distinguishable each with a type species viz., (1) *E. ravennae*, (2) *E. munja* (3) *E. arundinaceus*.

Anatomical studies also confirm that *Erianthus* should be separated from *Saccharum*. The genus *Saccharum* has probably only five species : (1) *S. officinarum*, (2) *S. spontaneum*, (3) *S. barberi*, (4) *S. sinense* and (5) *S. robustum* while *Erianthus*, *Sclerostachya* and *Narenga* should form separate genera.

Studies on the occurrence of starch in Saccharum :

Studies on the occurrence and amount of starch in the stem of sugarcane varieties have given an indication that the presence or otherwise of starch in the fully formed internodes is a specific character for certain species of *Saccharum*.

Chemical studies :

Extensive measurements have been made of the contents of sucrose, fibre, acidity, total nitrogen, gums, colloids, total ash, P_2O_5 , CaO, MgO, sulphates and K_2O .

Cytogenetical Studies :

On the basis of cyto-genetical studies it is considered that the North Indian canes have evolved out of extensive hybridization between *S. officinarum* and *S. spontaneum*. Though *S. officinarum* types are believed to have been introduced into India only recently it is possible that *S. officinarum* has been in cultivation in Peninsular India earlier than the North Indian indigenous canes.

It has been found that *S. officinarum* has two basic complements of $n=5$ each, and one of these is common to *Sclerostachya* and *S. officinarum*.

Cytological studies of *Erianthus* types and *Erianthus* crosses have shown the occurrence of polyploidy within the genus ; the various types falling under four chromosome groups viz., $2n = 20$, $2n = 30$, $2n = 40$, and $2n = 60$. The pentaploid or $2n = 50$ type which is missing in this series has not been synthetically produced by crossing *E. munja* ($2n = 60$) with *E. ciliare* ($2n = 40$).

At the instance of the Indian Council of Agricultural Research, a survey of sugarcane research in India was conducted and the report of the survey has been published by the Indian Central Sugarcane Committee.

DIVISION OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

Agricultural Chemistry deals with the soils, manures and fertilisers, plant products, food, feed and fodder and the nutrition of plants and animals, as also the interrelationship between them. Rapid strides have been made in recent years in our knowledge of soils, their genesis, morphology and classification, factors determining productivity of the soil ; and inter-relationships between the soil, the plant and farm animals. Soil science has emerged as a distinct branch of the Agricultural Sciences, and soil survey and soil mapping from the basis of scientific utilisation of the land and of the conservation of soil and water. While agricultural chemistry even deals with the application of chemistry to the study of the problems of agriculture including a general study of the soil, soil science deals with a specialised study of soil both in its pure and applied aspects. The major divisions of agricultural chemistry and soil science as they are now constituted are :—

Chemical analysis of feed, fodder, food, manures and fertilisers ; suitability of water for irrigation ; nutrient status of soils ; soil factors injurious to plant and animal growth ; soil surveys, soil classification and soil mapping for purposes of efficient and economic crop production ; irrigation ; afforestation and pasture development ; land reclamation ; soil amendments ; soil microbiology ; nutritive values of crops ; minerology of soils ; studies of clays ; soil physics ; study of insecticides and plant products.

In agricultural research stations increasing use is being made of such purely physico-chemical methods as spectral analysis of mineral constituents of soils and plants, X-ray analysis of the atomic structure of clays etc., electro-microscope, electrometric and conductometric studies, thermal analysis and others, for the study of the problems of agricultural chemistry and soil science.

The beginnings of the scientific study of agricultural chemistry and soils in India were made in the Indian Agricultural Research Institute. In recent years studies of these subjects on modern lines are being developed in the Indian Agricultural Research Institute, as also in several other centres. An account of the work done at the Institute is given below.

First Period (1905-1936) in Pusa, Bihar.

The work of the Division was started by Dr. J. W. Leather in 1905. He introduced methods of examining soils and crops followed at that time in Europe. Although there was nothing new in the technique which he followed, Leather may be given the credit of having trained a batch of workers in the methods of agricultural chemistry in this country. Most of his work corroborated or extended observations on similar lines in other countries.

Soil Studies.—The examination of soil sections and analyses of soil at different depths and salt and moisture in soils of different localities were made. He recognised four major-groups of soils in India : (1) Indo-gangetic alluvium, (2) Black cotton soil or *regur*, (3) red soils lying on metamorphic rocks and (4) laterites.

Drain Gauges.—Leather carried out investigations, the first of its kind in India, on the quantities of (a) run off of rain water, (b) amounts passing into the soil and (c) into drains, and (d) that evaporating from the soil surface. Four drain gauges were put up at Pusa on the same principles as those of Rothamsted. These consisted of blocks of arable land having a surface of 1/1000

of an acre which were isolated undisturbed and walled in, and had "false bottom". Two of them were 3 ft. deep and the other two were 6 ft. deep. Below were arrangements for collecting and measuring the drainage water. In addition, these gauges had overflow pipes connected to subsidiary tanks to measure the surface drainage (runoff). One drain gauge of each depth was left bare fallow. The other two were cropped with a wheat-maize rotation. The drainage increased with increasing rainfall, the quantity evaporating annually was nearly independent of the rainfall.

Gauge I

	Rainfall (in)	Drainage (in)	Overflow (in)	Evaporation and transpiration obtained by difference
1906-07	39.72	6.96	4.02	28.74
1907-08	21.92	nil	nil	30.46
1908-09	75.70	28.39	8.32	30.46
1909-10	52.20	6.41	nil	25.89

In agreement with the previous observations made by workers in other countries it was recorded that the effect of a crop was to reduce the amount of water evaporating from the soil. For instance, the total evaporation from fallow soil in a year was 24 inches, whilst that from the soil under crop was 16 inches. Hence the effect of the crop was to reduce direct evaporation to about 2/3rd of what it would occur from bare fallow. The amount of ammonia present in the drainage water both from bare fallow as also from cropped land was very small, amounting to less than 0.1 lb. N per acre, while the amount of nitrate especially in the years of good rainfall was high, above 200 lbs. NO₃-N per acre in years of average rainfall of 75 inches. The quantity of nitrate was also much higher in the drainage from the bare fallow gauges than from the cropped gauges, average of 4 years in bare fallow being about 70 lbs. NO₃-N per acre as against about 13 lbs. NO₃-N for cropped gauge. These observations were in conformity with previous observations in other countries.

It was also recorded that nitrification became very active after the onset of the rains and soon reached its maximum. Little of the nitrate formed during the first rains in summer was utilised by the crop since a large amount of it goes to the subsoil. Nitrate produced during the latter part of the monsoon was utilised by the next cold weather crop.

Water requirements of crops :—Investigations on the water requirements of crop were undertaken by Leather in 1907 and by experiments in glazed stone jars of varying sizes he measured the water requirements of a number of crops at Pusa. A summary of the results obtained is given in the following table.

Crop	Total number of pots used in tests	Mean water requirements
<i>Cold-weather crops—</i>		
Wheat (<i>Triticum sativum</i>)	23	544 10
Barley (<i>Hordeum Vulgare</i>)	4	468 12
Liats (<i>Avena sativa</i>)	4	469 40
Onseed (<i>Linum usitatissimum</i>)	6	807 49
Sarson (<i>Kali</i>) (<i>Brassica campestris</i>)	6	496 32
Pea (<i>Pisum sativum</i>)	4	563 28
Gram (<i>chikpea</i>) (<i>Cicer arietinum</i>)	4	818 77

Crop	Total number of pots used in tests	Mean water requirements
<i>Monsoon crops—</i>		
Maize (<i>Zea mays</i>)	31	337 7
Juar (<i>Sorghum vulgare</i>)	2	437 41
Murwa (<i>Kagi-Millet</i>) (<i>Eleusine coracana</i>)	2	263 2
Kodo (<i>Kodo-millet</i>) (<i>Laspalum scrobiculatum</i>)	—	312 4
Rahar (<i>Pigeon-pea</i>) (<i>Cajanus cajan</i>)	4	635 15
Guar (<i>Cyamopsis psoraleoides</i>)	2	598 5
Rice (<i>Oryza sativa</i>)	2	811 11
Sugarcane (<i>Saccharum officinarum</i>)	2	212 1

By far the most marked feature of the experiments on water requirements is the effect of manure on the transportation ratio. Speaking generally, the effect of a suitable manure in aiding the plant to economise water is the most important factor which has been recorded in the following table. The general conclusion was drawn that not only manure, but good tillage, a deep soil and indeed any factor which aids in good development of crop will tend towards an economy of water.

Crop	Period days	Transpiration ratio	
		No manure	Manured
Maize	90	450	330
Murwa	100	250	250
Kodo	120	300	300
Sarson	120	740	620
Barley	120	680	490
Oats	120	870	550
Peas	120	830	530
Gram	120	1,400	1,000
Linsed	120	1,000	1,000
Wheat	150	850	550
Juar	150	490	400
Guar	170	1,100	600
Rice	180	1,000	800
Rahar	240	1,100	600

The experiments of Leather show that an increase in the moisture content of the soil from 10 to 20 per cent. of saturation content does not affect the water requirements by an amount exceeding the experimental error.

These experiments with the drain gauges are the first and only one of its kind set up in India. The information collected from these and from his experiments on water requirements which also were first of their kind in this country is of basic scientific value.

Saline and Alkaline Soils:—In 1876 a "Reh Commission" was appointed by the Government of India to investigate the causes of the deterioration of land in Manipur District in the U.P. The occasion for its appointment was the appearance of "reg" alkali salts in a region which had previously been free from them. Subsequent investigations by Leather showed that the infertility of these lands had resulted from high subsoil water level, alkali deposit in the soil and the impervious nature of the soil, obstructing drainage. Extensive survey were also made of the alkali patches in the alluvial soil of Delhi, Unao, Lucknow, the Punjab, and the black soils under the Nira Valley Canal.

Application of gypsum followed by a plentiful supply of irrigation water coupled with ploughing were recommended for the removal of the alkali and for improving the bad physical state of the soil.

Permanent Manurial and Rotational Experiments :—The permanent manurial or long term experiment were started at Rothamsted by Lawes and Gilbert. The purpose of these experiments is to test the effect on soil and crop for one long range of climatic cycle and also to evaluate the acquired fertility of the soil, due to rotational, cultural and manurial operations for a fairly large number of years so that the short-term residual and other interfering effects are eliminated. The first series of permanent experiments in India were started by Leather at Kanpur but the treatments were not uniform through out. Two other series were started in 1908-09, one on alluvial calcareous sandy loam soil at Pusa (unirrigated) and the other on red and black soil at Coimbatore (irrigated).

At Pusa, during the period 1908-30, a 2 year-4-course (maize-rahar or pigeon pea-maize-oats) cereal-legume rotation was followed, on a soil type with a high content of calcium carbonate, which was neutral to slightly alkaline reaction. The soil was poor in organic matter, the carbon content determined by wet digestion method being 0.3 per cent.

The average yield data for all the years are given below.

Treatments per acre	Average yields in lbs. per acre (1908-30)				
	Maize (a)	Rahar (b)	Oats (c)	Barley	Peas
1. No manure	575	948	566	..	..
2. F. Y. M. 10 lbs. N	754	1,007	709	..	..
3. F. Y. M. 20 lbs. N	899	1,063	823	..	..
4. Rape cake 20 lbs. N	862	899	616	..	..
5. Ammonium sulphate N as in 3	541	881	450	..	..
6. Potassium sulphate K ₂ O as in 3	485	769	425	..	..
7. Superphosphate, P ₂ O ₅ as in 3	945	830	827	..	..
8. P+K as in 3	804	787	800	..	..
9. N+P+K as in 3	975	771	868	..	..
10. F. Y. M. 30 lbs. N	994	973	908	..	..
11. No manure in cereal rotation	473	..	429	336	..
12. G. M. in cereal rotation	777	..	635	422	..
13. One legume (rahar) in the rotation	544	722	457	..	..
14. Two legumes (rahar and pea) in the rotation	598	648	348	..	109
15. Legume (rahar) and G. M. in rotation	901	664	660	..	..
16. As in No. 15 but super to supply P2O5 as in No. 3 applied to G. M. crop	1,312	714	1,485	..	..

It will be observed that phosphatic manuring of green manure has given the highest yield of maize and oats followed by farm yard manure at 30 lbs. N per acre, which has again proved slightly better than N+P+K artificials at 20 lbs. N. Rape cake has given fairly good response with maize but not so with oats. Increasing doses of F.Y.M. has given increasing response. Both nitrogen and potassium singly have depressed the yields, but superphosphate alone has indicated very good response. Total cereal rotation has been found to be inferior to a cereal-legume rotation. Green manuring alone has proved highly beneficial to maize and oats but less so to the latter.

(a) Average of 22 crops.

(b) Average of 11 crops.

(c) Average of 11 crops.

With rahar F. Y. M. at 20-30 lbs. N per acre proved to be the best followed by rape cake. Artificially singly or in combinations and green manuring depressed the yields.

Soil analysis data show that the nitrogen and phosphoric acid status is low (N-O. 03 per cent., P_2O_5 -0.1 per cent.) but there is sufficient potash (0.39 per cent.) in the soil. Because of the high $CaCO_3$ content and the light sandy nature of soil as also the tropical heat, there is dearth of organic matter in the soil. Bulky organic manures, especially with phosphatic fertilisers, are therefore particularly suitable for such soil types.

A revised scheme of experiments came into operation from 1930-31 when a 4-year-8-course legume-cereal rotation was introduced (maize-barley-maize-rahara-maize-wheat-maize-peas). The average yields for 16 years from 1930-31 to 1945-46 are given below :—

Treatments lbs./acre	Average yield in lbs. per acre (1930-46)				
	Maize (a)	Barley (b)	Wheat (c)	Arhar (d)	Peas (e)
1. No manure	370	264	319	695	234
2. F. Y. M. 20 lbs. N	928	535	683	900	361
3. F. Y. M. 40 lbs. N	1,223	936	892	954	682
4. F. Y. M. 20 lbs. N	1,298	884	810	809	616
5. Rape cake 20 lbs. N	1,007	723	568	769	387
6. Ammonium sulphate 20 lbs. N	361	363	381	718	151
7. Potassium sulphate 25 lbs. K_2O	343	353	315	527	183
8. Superphosphate 40 lbs. P_2O_5	612	891	620	990	516
9. P+K	543	565	538	723	484
10. N+P+K	770	1,069	752	858	493
11. N+P	436	1,005	705	1,032	533
12. N+K	316	427	394	316	104
13. Green manure in cereal rotation	..	443	394	..	..
14. Cereals only	441	195	195	..	..
15. G. M. in legume rotation	596	745	599	482	247
16. G. M.+Super 80 lbs. P_2O_5	797	2,033	1,504	878	590

The results are in conformity of those observed during the earlier 22 years. For wheat and barley G.M. + P proved the best and for maize F.Y.M. at 20 lbs. N plus rape cake at 20 lbs. N/acre gave the best results. N + P + K artificials proved as good as F.Y.M. for wheat and barley but inferior to it in the case of maize.

Soil Temperature.—The temperature of the soil has an important influence on its physical and chemical properties as also on the crop, and more especially on microbial activity in the soil. The roots of crop plants are confined principally to the upper 2 or 3 feet of soil. Detailed records of soil temperature were maintained daily by Leather from 1910 for three consecutive years at several depths between one inch and 24 inches, in fallow and cropped plots. In bare fallow soil a close correspondence was observed between the soil temperature at 1 inch depth and the temperature of the air in the shade. The soil minimum at this depth however was about $20^{\circ}C$ higher than air minimum, and soil maximum about $3^{\circ}C$ higher than air maximum. A similar close relationship was found to exist between the diurnal changes in temperature in the soil (bare fallow) at 1 inch depth and the air in shade, the diurnal

(a) Average of 32 crops.

(b) Average of 8 crops.

(c) Average of 7 crops.

(d) Average of 8 crops.

(e) Average of 9 crops.

change being about 1.5°C greater in the soil than in the air. The temperature of soil near the surface (down to 3 or 4 inches) is above the mean temperature for only 8 hours and below it for about 16 hours. The lag in temperature change is about 2 hours at 3 inches depth and about 8 hours at 18 inches.

The effect of a covering crop on soil temperature was very marked, as it both prevented the surface soil from rising to the temperature which fallow land assumed and also modified the diurnal change. Thus while the temperature of the bare fallow soil at 1 inch depth rose to about 3°C about that of air, that of cropped land was about 2°C below it.

It has already been mentioned in connection with drainage experiments that the effect of a covering crop is to reduce the amount of water evaporating from the soil. This is apparently related to a considerable extent to the lowering of soil temperature. Humidity and the velocity of the wind are also factors which may considerably influence the soil evaporation. These points need further investigation.

Amongst investigations carried out by others in this Division before the transfer of the Institute to New Delhi, mention may be made of the following :

Black Cotton Soil :—One of the earliest works on the causes for the black colour of "regur" soil was a careful study of Annett. He attributed the colour to the presence of titaniferous magnetite and soluble humus. It is, however, now recognised that this explanation is not sufficient to account for the deep black colour.

Chemical Studies of Rice :—A detailed study of the nutritive value of rice was taken up early at the Institute. Rice collected from different places in Bihar and Orissa was found to contain a practically constant percentage of ether extract, fibre, ash, albuminoids and soluble carbohydrates, the last two comprising between 94 and 95 per cent of the total dry matter phosphoric acid is very slightly less than half the total mineral matter present and potash half of phosphoric acid. The average composition of husked rice on dry basis was found to be ether extract 2.68 per cent., albuminoids 8.50 per cent., soluble carbohydrates 86.14 per cent., woody fibre 0.86 per cent. ash 1.82 per cent. (total nitrogen 1.38 per cent. (albuminoid N 1.36 per cent.), phosphoric acid 0.86 per cent. and potash 0.41 per cent.).

Polishing of rice was found to cause a decrease in ether extract, fibre and mineral constituents as will be evident from a comparison of the following composition of polished rice on dry basis with that of husked rice given above. Ether extract 1.09 per cent. albuminoids 8.14 per cent., soluble carbohydrates 89.66 per cent., woody fibre 0.22 per cent., ash 0.89 per cent. (total N 1.30 per cent. (albuminoid N 1.28 per cent.), phosphoric acid 0.40 per cent. and potash 0.32 per cent.).

The assimilation of nutrients by the riceplant was also studied by chemical analysis at various stages of its growth. Total dry matter was found to increase up to the time of maturity. Percentage of nitrogen both in the portion above ground and the root decreased steadily from the first to the last stage ; 3.08 per cent. N in the whole plant i.e., root and above ground portion together, decreasing to 0.77 per cent. As the plant matured N, P_2O_5 and K gradually accumulated in the grain. Assimilation of these nutrients was practically complete by the time flowers appeared. Hence enough plant food must be available for the plant in the early stage. Taking the average yield per acre

of rice to be 900 lbs. dry grain, the soil loses in round figures 30 lbs. N, 10 lbs. phosphoric acid and 50 lbs. potash per acre by removal of the grain and the straw.

Estimation of available phosphoric Acid calcareous Soils :—Dyer's 1 per cent. citric acid solution as an extractant for estimating the available phosphoric acid in non-calcareous soils is widely used. For calcareous soils, however, this method is unreliable. Das used 1 per cent. solution of potassium carbonate which gives useful indication of the probable fertility of calcareous soils in their relation to available P_2O_5 . The method is followed in this Institute as also in soil laboratories elsewhere.

Soil Microbiology :—This section was started in 1909 under the charge of Hutchinson. During the early period, in addition to the work on problems of soil microbiology connected with soil nitrogen, investigations were carried out on the utilization of indigenous phosphates, decomposition of green manure, the production of toxic substances by bacterial agencies, bacterial diseases of plants, diseases of silk worm, alcoholic fermentation, and the transformations caused by bacteria in the process of manufacture of indigo. The micro-organisms in some Indian soils were studied as also their role in oil fertility.

Azotobacter strains were isolated from soils from Pusa, Kanpur Darjeeling, Bangalore, Nagpur and Sind. The nitrogen fixing power of the different strains was found to vary from 3.5 to 7.4 mgs. per gm. of mannite added. The azotobacter plaque method was used for obtaining information on the phosphate deficiencies of several soils.

No marked gain in nitrogen was observed in the soil when the whole leguminous green manure crop was removed. Inoculation of a particular legume with its specific organism was found to give better performance than with organisms from other legumes in confirmation of results obtained elsewhere. A considerable amount of work was done in the earlier years on the nodule bacteriology of berseem. Nitrogen availability of a number of organic and inorganic manures in Pusa and other soils was studied with the object of assessing the economic return.

Nitrification of calcium cyanamide was studied in a number of soils and was found to be different in different soils.

An organism yielding a butter flavour to curd (dahi) was isolated. The production of diacetyl by this organism compared very favourably with that produced by some of the best American cultures.

A method of composting bone meal was developed by Vyas which could solubilise about 60 per cent. of the total P_2O_5 within a period of 6—8 months.

Nitrification of different oil cakes added at the rate of 30 mgms N per 100 gms. of Pusa soil was studied with moisture equivalent to 1/3rd saturation at 30°C. Castor cake, of both white and black varieties, nitrified to the extent of 88 per cent. which was followed by other oil cakes in the order nigarm linseed, sarson, karang, groundnut, nim, and safflower and these were followed by decorticated cotton seed and undecorticated cotton seed; the percentages of nitrification of these were respectively 85, 80, 80, 75, 72, 72, 72, 56, 45, and 20. Mohua cakes did not nitrify at all. Soluble phosphate in the form of K_2HPO_4 added at the rate of 0.25 gm. per 100 gm. of soil enhanced nitrogen transforma-

tion, but 0.5 per cent. and above retarded the process to an appreciable extent. Glucose when added at the rate of 0.5 gm./1000 gm. of soil brought about a decrease in nitrification.

Second Period (1936-45) in New Delhi.

The important results during this period are given below :—

Soil Map of India.—In 1932, Schokalsky, prepared on the basis of information supplied to her, for the first time, a soil map of India. It was based mainly on the physiographical and geological features. In 1935, the Geological Survey of India undertook a general survey of soils and a map was published by Wadia, Krishnan and Mukherjee describing the geological foundations of soils of India. The necessity for preparing a soil map of India based on soil characteristic was, however, strongly felt, and accordingly in 1943, Vishwanath and Ukil in collaboration with other soil workers prepared such a soil map. They also attempted to correlate the soil characteristics with the climatic data mainly N.S. Quotients.

All India Soil Survey Scheme.—Soil classification in India for revenue purposes begins from the time of Todarmal (17th century) and quite a mass of soil survey on any systematic basis has not been carried out so far except in a few instances. Amongst important recent works mention may be made of that carried out in the Deccan Canal areas in Bombay, Irwin Canal areas in Mysore and Hyderabad, Kulu Valley areas in the Punjab, and the Kumaun Hill tracts of the U.P. Besides, studies on the red and laterite soils have been carried out at the University of Dacca, coastal soils of Bengal at the University of Calcutta, and on the soils of Assam and other tea growing areas by the Department of Agriculture of Assam and mostly by the experimental station of the India Tea Association at Tocklai.

The Crops and Soils Wing of the Board of Agriculture and Animal Husbandry in India in 1935 emphasised the necessity for carrying out reconnaissance soil surveys. Sir John Russell, in 1937 in his report to I.C.A.R., also recommended the collation and examination of the available data on soil analysis with a view to the preparation of a soil map of India. As a result of these recommendations the I.C.A.R. financed an All-India Soil Survey Scheme in this Institute which came into operation in 1943 and the final report was prepared early in 1946. The report is now in the press.

Nitrogen, phosphoric acid and potash contents of Indian soils.—In the early studies of soils the fertility status was assessed by determining nitrogen, phosphoric acid and potash contents of the surface layer of soil. Such fertility surveys, as they were called, were carried out in Madras, Travancore and some other places, and on the basis of this information, maps for India showing the N, P and K contents were prepared in this Institute. A map showing soil pH was also prepared.

Soil Fertility.—Phosphatic fertilisers applied to berseem increased the nitrogen level in the soil and also its fertility as measured by the residual effects on wheat. The evolution of CO₂ from soils in Pusa and Delhi farms has been studied in its relation to soil fertility.

Nitrification.—Investigation on the nitrification of mustard oil cake in 57 soils collected from agricultural stations all over India showed that the samples collected from stations lying in a narrow belt running from east to west across the middle of India and which included various soil types, did not nitrify beyond 25 per cent. of the added nitrogen in the soil with 1/3rd saturation with water. They, however, showed improved nitrifying power with higher moisture contents.

Utilisation of cowdung both as fuel and as manures.—Better utilisation of cowdung has been achieved through a process of anaerobic fermentation by means of which cowdung can be used both as a manure and as fuel gas. The residue, after evolution of a mixture of methane, a small percentage of hydrogen and carbon dioxide, which has a calorific value of about 500 B.T.U. per cubic foot, retains the nitrogen and is equal to farm yard manure in its manurial value. Evolution of gas varies with the atmospheric temperature, being 10 cft. in summer and 2 cft. in winter when charged with cowdung at the rate of 150 lbs. per fortnight. A total output of 1 cft. of gas per lb. of raw cowdung has been observed. The economics of the process require, however, to be worked out on a large scale.

Butanol and acetone from molasses.—Butanol and acetone have been prepared out of molasses with the addition of groundnut cake. A suitable bacterial culture has been isolated and a patent has been taken.

Manufacture of gur and sugar.—Experiments on gur and sugar manufacture by the open pan process have shown that under liming (pH 6.0 to 6.3) and carbon clarification of the juice yields a gur of pleasing colour, good texture and structure, with less of invert sugar, while a 7 per cent. recovery of sugar (Khandsari) on cane is obtained.

Rubber.—During world war II a large number of lateciferous plants were examined and *Cryptostegia grandiflora* was studied in detail to determine its possibilities as a source of rubber. The method of tapping, the most suitable time of the day and the frequency of tapping were worked out. Rubber was obtained from the latex by diluting it with water and an yield of 130 lbs. rubber per acre per annum was obtained.

Third Period (1945-49)

The scope of work on agricultural chemistry and soil science has been referred to earlier in this section. Within recent years a great increase in our knowledge of the soil has been achieved.

For most of the manurial experiments in India including the permanent manurial experiments at Pusa, Kanpur and Coimbatore, much relevant information about the soil is lacking. The importance of such data has been stressed by Russell and Stewart in their reports to the I.C.A.R. Recent survey of the I.A.R.I. farm at New Delhi has shown that its soils are heterogenous due to levelling of uneven land and this heterogeneity seems responsible in part for lack of correlation in the results of many manurial trials in the Farm. The irregular results of the experiments suggested by Sir John Russell and conducted at this Institute emphasised the need for a detailed study of the soils and for the preparation of a map of the farm.

The importance of soil survey for agricultural development has been recognised only in recent years but the methods of survey have not been uniform in different parts of India. During the year under report the Ministry of Agriculture, Government of India, has instituted a Central Committee of Soil Science in order to standardise the methods of Soil Survey.

In the classification of soils, the study of the parent material in relation to the parent rock is very important. For this purpose a trained geologist is needed. Besides soil survey itself requires persons specially trained in modern methods of soil survey including contour mapping, profile examination in the field and cartography.

Modern soil studies have revealed the importance of a knowledge of the nature of clays and clay minerals in the soils which determine to a very marked extent many aspects of soil behaviour. For this purpose, studies on thermal dehydration, electro-chemical and X-ray analytical methods are important which can be taken up only by men trained in physical chemistry. For the development of these techniques as also the techniques of spectral analytical methods for detection and estimation of the plant nutrients, particularly the trace elements as also vitamins the services of a competent physicist is a necessity. The studies of soil moisture, permeability and porosity of soils are very important aspects of soil classification and soil fertility and require the services of a soil physicist.

The study of the role of micronutrient or trace elements in plant nutrition has attracted great attention all over the world. Many pathological diseases of plants and animals known as deficiency diseases have been recognised to arise from deficiencies of one or more of these micronutrient elements. Special techniques are needed for the study of these important elements. Some work on this line was done earlier in this Institute. But the techniques followed were not suitable for the purpose. Work has now been started with more modern techniques.

Study of the nutritive value of food, feed and fodder is a major branch of agricultural chemistry. The quality of food grains, vegetables and fodder and their improvement has attracted for years wide interest all over the world. Marked progress has already been made abroad in improving their amino acid and vitamin content by hybridization and selective cultivation. Development of alternate dairy feed for cereals like oats which are costly and are not grown in all parts of the country has also been taken up. For investigation of such problems the opening up of a section of biochemistry was felt necessary.

The work on insecticides and fungicides as also on the chemistry and utilisation of plant products is of great importance in agriculture. A separate section for this work has been started. Work on the synthesis of insecticides and on the study of insecticide of plant origin has been taken up.

The work in other branches such as soil microbiology and agricultural chemistry has been strengthened and their scope expanded during the period under review. For various reasons, however, recruitment of new staff for the Division has taken some time.

Main lines of work which had been taken up before the expansion of the Division were continued. Investigations mainly in soil science which were started recently are briefly reviewed below. The number of analyses per year of soils, plant materials, manures, fertilisers, feeds, and fodder has increased during the year under report (1948-49) approximately to about 60,000, including those in research projects as against 3,500 in the previous year.

Soil Survey.—The survey of the farm areas under the Institute and its substation at Karnal have been undertaken. At the request of various other Government Departments soil survey of reconnaissance type were carried out at several places and recommendations about their suitability for use for special purposes were made. A large number of instruments essential for soil surveys have been purchased, and the section may now be said to be fully equipped.

Delhi Farm.—Due to the levelling of the farm at the time of layout a considerable difficulty was met with in determining the normal soil type.

Examination of a number of profiles of the Delhi farm shows that these soils are sandy to sandy-loam, the content of sand being between 50 to 60 per cent. and that of clay between 15 to 20 per cent. The presence of free carbonate in the form of 'kankars' is a common feature and occurs at different depths varying from 4 to 5 ft. where soil was not disturbed, whereas in disturbed soil it starts from the surface.

Due to the levelling of the farm at the time of layout, a considerable portion of top soil was disturbed and in some places a top soil upto 3 ft. was removed. In order to understand the layout of the farm a map showing the fill-up portion and the portion from where the soil was removed was prepared.

It was also found that the water-table of the farm was rising. A survey of the water table depth at different seasons was undertaken and it was found that the water-table during monsoon season was within 3 ft. at several places while in winter or rabi season it receded to only 4 to 5 ft. Steps have been taken to avoid seepage losses and excessive use of water irrigation as far as possible. Means of securing efficient drainage is under consideration.

Karnal Farm.—The base map of the farm of the Agricultural Substation, Karnal, has been prepared. The soil of the farm areas are generally grey-brown silt loam and the colour changes to yellowish brown depth. The profiles show concretions of iron and carbonates in lower depths. Extensive saline patches occur within the area and at some places soils have turned alkaline.

Rapid Reconnaissance Surveys in the Provinces and States.

1. *Gaurikund, Ajmer.*—A rapid reconnaissance survey of about 200 acres of the land in Gaurikund, Ajmer showed that these soils were of sandy texture, the clay content being only 5 to 7 per cent. while sand was between 89 to 92 per cent. The total soluble salts were very low and were about 0.3 per cent., the pH was between 7.9 to 8.2 and the base exchange capacity was 4 to 6 m.e./100 gm. soil. These soils were also poor in other plant nutrients, the content of nitrogen being only 0.01 per cent. while total P_2O_5 was about 0.03 per cent. Total potash however was about 0.6 per cent. C/N ratio is about 8 to 10. The texture being sandy the soils would require application of organic manure. Irrigation would have to be judiciously used in quantities not in excess of what was necessary and with shorter intervals. Much water was likely to be lost by percolation.

2. *Bhadruk Farm, Lucknow.*—A rapid reconnaissance survey of 500 acres of the farm showed that the surface layer (0—7") was either sandy loam or loam while at lower depth the soils were of clay loam in texture, clay content being between 16 to 30 per cent. in the lower depth. The total soluble salt was below 0.2 per cent. and was generally of the order of 0.06 per cent. The pH was between 6.9 and 7.9; the lime status of these soils was rather poor; the base exchange capacity was low being 11 m.e./100 gm. soil; the exchangeable calcium was generally very low and in a few cases it was only about 50 per cent. of the exchange capacity. From the analyses and the morphological examination of profile it could be said that though the internal and external drainage of these soils were good and the salt content low, in order to bring the land under irrigation for sugarcane cultivation the content of exchangeable calcium should be raised. This requires application of gypsum or superphosphate to the soil together with proper drainage facilities. A map of the present land use of the area was prepared.

3. *Jubbulpore*.—About 3000 acres of land of Jubbulpore near Khamaria Ordnance Factory was surveyed. The laboratory analysis showed that these soils contained clay between 44 to 53 per cent. All these soils were low in plant nutrients, having 0.03 per cent. N, 0.05 per cent. available P_2O_5 and 0.04 to 0.06 per cent. available K_2O . The base exchange capacity was between 33 and 39 m.e./100 gm. soil and exchangeable calcium was of the order of 33 to 35 m.e. Exchangeable sodium was only about 2 to 3 m.e. while potash was about 3 to 4 m.e. The percentage degree of saturation of the divalent bases was on average about 90 per cent. A land utilisation map of the farm area was prepared.

4. *Rann of Cutch*.—A rapid reconnaissance survey was carried in 1947. The soils contained total salts ranging from 2 to 17 per cent. of which about 75 per cent. was sodium salt, the test being made up of gypsum and other salts. In several areas crystalline gypsum bands occur which in some cases amount to about 600 tons per acre within the first 2 ft. There was considerable amounts of flood water draining through this area which would be useful for reclamation purpose. The analytical data and base exchange capacities of clays separated from these soils showed that illite or mica group of clay mineral was predominant in these soils.

Basic Soil Regions.—A classification of soils of India into basic soil regions based on similar characteristics of the land *viz.*, the climate, topography, vegetation and soils are being carried out. Such a classification will supply a fundamental scientific and practical basis for the planning and utilisation of land for more than one purpose.

Studies of Clay and Clay Minerals.—The clay complex is the active constituent of the soil, and the important role played by it in governing the base exchange capacity of soil, in its interaction with fertilisers and lime and in general in determining the physical and chemical properties of the soil is now well recognised. Studies in this field include buffer capacities, titration curves with bases, free and titratable acids in absence and in presence of neutral salts, displacement of aluminium and iron by neutral salts, variation in viscosity of clay suspensions with increasing base saturation and use of membrane electrode

In the study of clay and related minerals techniques commonly employed in mineral analysis are not of much help. Chemical analysis is of limited significance for characterising clays, because of the presence of more than one clay mineral, of free silica and sesquioxides and of isomorphous replacement within the lattice. These, however, can be corroborated by such other methods as X-ray, thermal and optical studies. The X-ray examination of clay sample usually shows the major constituents only and the method therefore has its limitations. The electro-chemical and viscosity properties of clays however give information of the constitution and properties of clays and clay minerals of great significance to soil science. These methods have been used in investigating the nature of clays prepared from several horizon samples of a black cotton soil profile from Indore. The dominant clay mineral present in them has been found to be montmorillonite, although illite, to the extent of 20 per cent. is also present.

Manures and Fertilisers.—Experiments on new sources of green manures were initiated. A survey of wild leguminous plants, shrubs and trees in Delhi has shown that many of these species are potential sources of green manures as also of fodder; the nitrogen, phosphate and lime contents of their leaves being, in several cases, as high as those of common green manure crops like berseem and

sannhemp. In *Cassia occidentalis*, for example, the contents of nitrogen is even higher, being 5.9 per cent. while the values for berseem and sannhemp are 3 per cent. and 2.3 per cent. respectively. Lime and phosphate contents of the leaves are also comparatively high.

Foliar Diagnosis.—The technique of foliar diagnosis methods of correlating the crop yields and manurial treatments was tried on the Pusa permanent manurial plots. Periodical analysis of barley leaf samples showed that an accumulation of nutrients in the leaf, particularly in the early stages of growth, is associated with low yields of the final crop, while a gradual and sustained mobilisation of nutrients from the leaf to the plant in the early stages of growth is a marked feature in plots which give higher yields. This is evident from the following table :—

Treatment	Yield of grain & straw in lb. per acre.	N% in barley leaf			
		Stage 1	2	3	4
Control	496	4.14	4.27	4.25	3.74
F. Y. M. 8,000 lbs. per acre .. .	1,768	5.72	3.58	3.08	2.94

The symptoms indicating deficiencies of nutrients using indicator crops like potato, oats, rape, sunflower, berseem, lettuce and gram were being studied by recording visual symptoms and rapid tissue tests.

Micronutrient Elements.—Deficiency diseases of citrus were studied. Inter-venal chlorosis of citrus with die back in severe cases and small size of leaves in Coorg was traced to manganese and zinc deficiency and the spraying of these chemicals has given encouraging results in correcting the disease.

The distribution of various forms of manganese in the soils from different parts of the country was being studied. Soils of the perhumid zone and soils of calcareous nature has been found to contain low amounts of available manganese.

Gram was observed to show 'top yellowing', 'bronzing' and 'yellow and bronzing'. These symptoms were not found to be associated with pathogenic organisms. The study of these diseases in relation to nutritional deficiencies on the other hand revealed that leaves of gram plants showing 'bronzing' and 'yellowing and bronzing' symptoms contained low amounts of phosphorus and boron as compared to healthy leaves, while in plants showing 'top yellowing', manganese was found to be low. An accumulation of nitrate and also nitrate nitrogen in the soil near the root zone of unhealthy plants was also noticed.

Deficiency of some micronutrients like cobalt and copper in forage crops has sometimes been found to be responsible for certain nutritional diseases in cattle. Investigation on this line have been taken up with a view to study the micronutrient status of fodder grown at the Institute farm for the feed of the cattle. The different varieties of grasses grown in the nursery in the Division of Agronomy are also being studied for their nutritional deficiencies.

Work on the quantitative estimation of boron by spectrographic method was started with a medium Quartz Spectrograph in this Division earlier. As greater accuracy in the estimation of all the trace elements is possible with larger dispersion instruments an automatic large Quartz spectrograph has been obtained. This instrument with the necessary equipment ordered for will facilitate the use

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of the latest techniques such as Cathode layer arc technique where accuracy in estimations will be increased many folds. An Intermediate Quartz spectrograph also has been purchased to start Lundegardh flame method for the estimation of major elements. This may also be useful for absorption spectrophotometric measurements for the estimations of vitamin etc.

Fixation of Nitrogen.—Experiments carried out with superphosphate and insoluble phosphates like ground bone-meal, Trichi nodules and Singhbhum phosphate showed that all of them increased the nitrogen fixing power by leguminous plants. The amounts of nitrogen fixed per pound of P_2O_5 added in the above form worked out 0.93, 0.85, 0.34, 0.29, lb. of Nitrogen respectively.

Recent investigation on inoculation of Rahar and gram has revealed that while gram derives benefit from inoculation, rahar does not.

A few aspect of the problem of nitrogen fixation of azotobacter is that, in combination with a type of actinomycetes which is found in association in all soils examined, there is indication of fixation of a higher amount of nitrogen (by about 30-40 per cent.) than without the actinomycetes. A type of organic soil, locally known as 'kari' containing about 30 per cent. organic matter occurs in Travancore. The pH of this soil is below 4.0.

Azotobacter has been isolated from this soil which has been found to fix as much nitrogen as that from either Delhi or Nagpur.

Insecticide and fungicides.—Synthesis of some halo-and thiocyno derivatives of terpenes have been taken up. Preliminary tests on some of the compounds show that they are promising as insecticides against aphids.

Compounds	% purity	Average Percentage Mortality.		
		C. Cephalonica		R. pseudo-brassicæ
		After 2 days	After 7 days	after 2 hours
Control (10% benzene emulsion)	..	..	6.7	3.0
Isobornyl thiocyanacetate	97.2	5.5	44.4	100.0
Nopyl thiocyanacetate	81.5	30.0	55.0	100.0
Than'te (Hercules Powder Co. U.S.A.)	82.00	5.0	10.0	100.0
Pyrocolloid (Bombay Chemicals Ltd., 3% Pyrethrins)	..	100.0	100.0	100.0

Biochemical studies on Tomatoes.—Biochemical studies of hybrid varieties of tomatoes developed by crossing different cultivated varieties with wild ones have been made. Many of them contained much more vitamin C than the cultivated ones as evident from the values 23.29, 46.79, and 34.60 mg. per 100 gm. fresh material for cultivated, wild and selection varieties respectively.

Chemical Composition of Indian Grasses.—Fifteen varieties of indigenous grasses were analysed in cuttings obtained from the same plants at intervals of one month and also at different stages of growth. Some of the grasses, such as, *Sataria palmifolia*, *Phalaris minor*, *Themeda tremula*, *Cenchrus ciliaris* etc. have been found to be very promising, their protein content varying from 12 per cent. to 15 per cent.

Chemical Composition and Nutritive Value of Wheat.—In view of the earlier work of this Institute, wheat grown under different manurial treatments in the Permanent Manurial and Rotational Experiments at Pusa (1948-49) was

analysed for its chemical composition and vitamin content. The work is being continued with another wheat crop (1949-50). Correlation will be made when this analysis is completed.

Soil Enzymes.—An apparatus has been set up for studying the activity of enzymes elaborated by micro-organisms in the soil. Its advantage lies chiefly in reproducibility of results as well as in rapidity and simplicity of the method.

DIVISION OF ENTOMOLOGY

The first period (1905-1936)

Previous to the formation of the Entomology Section of the Agricultural Research Institute at Pusa, taxonomic work in Entomology had been carried on in the Entomological Section of the Indian Museum since the foundation of the latter in 1866 but it was not till 1888 that the Government of India recognised the importance of the study of crop pests arranged with the Trustees of the Indian Museum for their identification and study by the Entomologists of the Museum. This first step constituted the development of applied Entomology in India. Towards the end of the nineteenth century a considerable amount of work on this subject was being done in India. The names of Wood-Mason, Atkinson, Swinhoe, Dugdon, Hampson, Greene and others on Lepidoptera and other groups of insects may be recalled because of their important contributions. In 1901, the post of Entomologist to the Government of India was sanctioned with headquarters at the Indian Museum, Calcutta. On the establishment of the Institute at Pusa in 1905 the post of the Entomologist to the Government of India was transferred to the latter and the designation was changed to 'Imperial Entomologist.'

About 30 years were spent in laying a solid foundation of Indian Entomology. The basic information about the insect fauna of India was collected and consolidated. As the Indian field was practically virgin, the exploration work started with maximum speed and Maxwell-Lefroy produced an important manual of practical information—"Indian Insect Pests", as early as 1906. This publication was soon followed in 1909 by a monumental treatise in two large volumes entitled "Indian Insect Life" by Maxwell-Lefroy assisted by F. M. Howlett. The treatise constitutes the foundations of entomological knowledge in India and it was followed up by a period of patient work on (a) life-histories of pests of importance, (b) building up of insect collections, (c) studies on bionomics and distribution of pests and parasites and (d) devising of control measures and advising the central and provincial governments. A large number of research contributions were published. The investigations on lac and silk insects at the Institute led to the establishment of separate research stations, the Sericultural Research Institute, Bhagalpur (Bihar) and the Indian Lac Research Institute, Ranchi (Bihar). Also during this period the provincial departments of Entomology came into existence in Madras (1912), Punjab (1919), U.P. (1922) and C.P. (1933). The Indian Agricultural Research Institute almost invariably supplied the trained personnel for them. Five Entomological Conferences were called by this Institute resulting in the publication of proceedings giving full details of papers read by entomologists deputed from the various provinces and States. These publications serve as valuable works of reference on Indian Entomology.

The second period (1936-1945)

During this period there was an expansion of staff and consequently of investigation projects. A number of schemes financed by the Indian Council of Agricultural Research, namely, (a) All-India Survey of Pests and Parasites on Sugarcane followed by Biological Control of Sugarcane Pests, (b) Leaf-curl Diseases of Tobacco, (c) Survey of *Icerya purchasi*, (d) Pests of Stored Jowar, and (e) Population studies, added to the activities of main section. These were further enhanced from 15th April 1939 when the Government of India took over on a permanent basis the scheme on Desert locust which had been in existence under the Indian Council of Agricultural Research since 1931.

Collection and identification of insects :

During this period the existing collection was enriched by further additions of named and valuable insects from time to time. This collection, which is now known as "The National Pusa Collection", is one of the largest and best representative collection of the East. It now contains about 1,10,000 named specimens of insects belonging to 15,000 species besides a large collection of unnamed material awaiting identification. Records of the time of occurrence, range of distribution in time and space, food-plants, natural enemies, etc., of most of the important insects of economic importance in the collection has been collected and maintained. The utility of the Pusa Collection is not only limited to India but extends to neighbouring countries also, as a large number of insect genera and species are common to Africa, India, Persia, Afghanistan, Burma, Federated Malaya States and the Far East, from which many enquiries as regards identities of insects and their geographical distribution are received from time to time.

Taxonomic studies were taken up from the very inception of the Institute and have been continued up to the present day. So far 131 new species, 5 new genera and 1 new sub-family have been described. This includes descriptions of a large number of Chalcidoidea, Serphoidea and Evanidae. While two parasites of Sugarcane *Pyrilla* were previously known, several are now recognised.

The correct identification of the various species of lepidopterous borers of sugarcane all previously grouped under the name *Chilo*, was established and twelve species of the group are now recognised. Besides this, keys to the identification of the larvae and pupae of the twelve borers were prepared and published. Twelve catalogues of Indian insects belonging to various orders have already been published.

Desert Locust, Schistocerca gregaria Forsk :

As stated earlier, the Government of India took over in 1939 from the Indian Council of Agricultural Research, the Locust Research Scheme which under the auspices of Government of India became known as Locust Warning Organization, its main function being to watch the waxing and waning of the locust population in North-West India and in emergent cases to send warning notes to areas of locust visitation. Thus except for survey work, no research work of any fundamental importance was taken up by the organization.

Ecological and Epidemiological studies :

During this period detailed study was undertaken on the effects of temperature and humidity on the development of *Earias fabia*, the spotted bollworm of cotton and that of its chief parasite *Bracon (Microbracon) lefroy*. It was found that although the threshold of development of both the pest and the

parasite lies at about 12°C, and long continued exposures to lower temperatures are fatal to both, yet on the whole lower temperatures and higher humidities are comparatively more unfavourable to the host than to the parasite. The practical effect of this differential behaviour is that "rains in summer help in controlling the pest by lowering the temperature which is beneficial to the parasite and raising the humidity which is injurious to the host." Similar studies were also carried out on *Goryphus (Melcha) nursei*, another important parasite of *Earias* spp. and *Melcha ornatipennis*, a parasite of top-borer of sugarcane, *scirpophaga nivella*.

Temperatures lethal to the pink bollworm of cotton (*Platyedra gossypiella*) were re-investigated under Indian conditions with a view to establish the feasibility of heat treatment of cotton seeds which had already been "followed in other countries and recommended for adoption in certain parts of India." These chief observations showing the margin of safety between heat exposures fatal to the larvae and those injurious to the viability of the seeds were:— (a) that for treatment of cotton seeds spread in a thin layer, an exposure of a little over three hours to 50°C., 40 minutes to 55°C., 15 minutes to 60°C., 7 to 10 minutes to 65°C., or 3 to 5 minutes to 70°C. is completely fatal to larvae within the seeds; (b) that the viability of cotton seed is not affected materially upto an exposure of about 30 minutes to 65°C., 20 minutes to 75°C. or 10 minutes to 80°C.

In 1940, a new line of investigation on the epidemiology of cotton bollworm was taken up. Based on precision experiments carried out in other countries with other pests, the technique of sampling and of studying the distribution of spotted bollworm of cotton was standardised. Various existing methods of computing pest incidence were checked up and it was shown that the best was that of population per acre. The following correction for the cumulative effect of weather conditions on insect population was suggested: $Y = X/Z$ where X is the actual count, Z the developmental period of the stage counted and Y the corrected index of the population. There had been a confusion among earlier workers as regards the relative effect of the constant temperatures of the laboratory and the fluctuating temperatures of the field. Some had recorded quicker development under fluctuating temperatures than under constant temperatures and others had observed just the opposite phenomenon. A new explanation for these conflicting observations was put forth showing that the mathematical relation between temperature and rate of development was such that below a certain critical temperature the development should be quicker under fluctuating temperature than under constant temperature and that above that critical temperature this relative effect should get reversed. On the basis of known facts regarding development of living organisms and a few simple hypotheses the following equation connecting rate of development with rise of temperature was deduced:

$Y = Y_0 e^{-aX^n}$ where Y_0 = highest value of developmental index, Y = developmental index at temperature t , $n = T - t$; T = temperature corresponding to Y_0 and e = constant. This equation was successfully fitted to ten different sets of observations published by earlier workers on the development of different stages of *Earias fabia* (Lepidoptera), *Microbrachion lefroyi* (Hymenoptera) and *Schistocerca gregaria* (Orthoptera).

On the basis of the above mentioned studies a convenient and simple device called 'Biometer' was evolved for estimating the developmental period and number of generations of a pest under the natural temperature fluctuation in the LSICAR

field. It consists of a thermograph chart which is transparent and in which the horizontal lines instead of showing temperature indicate the calculated rate of development of the pest concerned corresponding to different temperatures. When this transport chart is superimposed over the thermograph record of any locality, we can directly read the rate of development at the different points of the time scale. Further as the ordinate of this chart represents the rate of development and the abscissa the time, the area below the temperature line directly gives the amount of development. Different portions of the area are not equal in value because the relation between temperature and rate of development is not linear. This difficulty is avoided by estimating the area not by a planimeter but by counting the cells formed by horizontal and vertical lines. These cells differ in area but are equal in developmental value. This device has a number of advantages over the old method of thermal summation. Obviously it should be possible to make similar biometers for a number of vital phenomena which are affected by temperature.

Insect Pests of Sugarcane :

The identity, distribution, incidence, and control of sugarcane borers which collectively cause a loss of at least 10 per cent. of the crop has been studied from the beginning of this division.

As a result of coordinated research on control of sugarcane pests by cultural and mechanical methods at different centres in India, the following control measures have been unanimously recommended by the Expert Entomological Committee of the Indian Central Sugarcane Committee for general adoption by cultivators in various parts of India : (1) Earthing up of young canes for the control of stem and root borers in Madras, U.P., Bihar and Hyderabad ; (2) Removal of dead-hearts for the control of borers in Bihar ; (3) Stripping of cane for control of *Pyrilla* in U.P. ; (4) Digging out of canes in preference to cutting them at ground level for the control of borers in Madras ; (5) Collection of eggs and moths of the sugarcane top borer and their destruction in Punjab ; (6) Hand netting and bagging of *Pyrilla* nymphs and adults in Punjab ; and (7) Destruction of stem borers by spike thrust method, in the early stages of the crop in Madras.

A coordinated programme for the biological control of sugarcane stem and root borer, by means of the parasite, *Trichogramma evanescens minutum* was planned at different centres and promising results have been obtained in Madras, Bombay, Bihar and Orissa. Besides, the biology of a number of promising parasites and predators of potential importance has been studied. The host parasite relationship of the lepidopterous parasite (*Epipyrops melanoleuca*) of the sugarcane leaf-hopper, *Pyrilla* was worked out and published.

Insect Vector of Virus :

Tobacco is known to suffer from a virus disease which causes curling of leaves, twisting of stem and inhibiting the growth of the whole plant in several parts of the world. In India, the disease is most common in Bihar, Baroda and Bombay Province. The cigarette varieties of tobacco are especially susceptible to the disease.

As in other centres the white-fly, *Bemisia tabaci* (Gen.) has been found to be the most important vector. The alternative hosts of the tobacco leaf-curl viruses at Pusa were sunn-hemp, *Ageratum conyzoides*, *Zinnia elegans*, *Euphorbia hirta*, *Vernonia cinerea*, tomato, *Launea asplenifolia*, *Sida rhombifolia* and *Scoparia dulcis*.

Stored grain pests :

The important insect pests of jowar in storage are about a dozen insects. If the moisture content of the grain is 7 per cent. or less the damage due to pests is quite low. At 12 per cent. or more they multiply rapidly. Heating at 55°C for 15 minutes kills all these pests without affecting the seed germination.

Codling moth, *Cydia* (= *Carpocapsa*) *pomonella* (Linn.)

The codling moth, an important pest of some fruits, was observed causing serious damage in Baluchistan by a member of this Division in 1932-34. There was previous mention of this pest having been found in Kashmir in 1900 but it was not identified. The complete biology of the pest was worked out under Indian conditions and published in 1938.

Cottony cushion scale, *Icerya purchasi* Mask :

An extensive survey of this serious pest of citrus trees of India revealed several new alternate food-plants, besides those already known and also the localities to which this pest had spread since its entry into this country from Ceylon.

The present period (1945-1948)

The Division of Entomology as re-organised consists of the sections of Insect Taxonomy, Insect Parasitology, Insect Ecology and Toxicology. In the Section of Parasitology, new breeding techniques are being evolved which are based on studies on the effects of nutrition, temperature, humidity, light, etc., on the sex ratio, fecundity and longevity of parasites. Mass production of parasites is now a regular feature of the work of this section. In the Section of Toxicology studies are in progress with known insecticides under Indian climatic condition as also with new synthetic chemicals under different conditions of temperature and humidity. Also investigations are being carried out on the manner of action of insecticides. In the Section of Ecology studies have been undertaken on insect epidemics. Annotated lists of insects in the National Pusa Collection are under preparation. Systematic studies on the Taxonomy of Bruchids are in progress in the Section of Taxonomy. The main results achieved under the different Sections since 1945 are summarised below :—

Identification, cataloguing and listing of insects

(a) Eight species of parasitic Hymenoptera have been added as new to science, (b) Taxonomy of Isoptera has been worked out and a catalogue of species occurring on India, Burma and Ceylon has been prepared for publication, (c) Recently a catalogue of Oriental Bruchidae has been completed, and (d) Two new species of Cucurliionidae and one species of Cereidae have also been described. Listing of insects of various orders in the collection are in progress.

The structural differences of the genital armature are being used for the determination of the genera and species of Bruchids. The family Bruchidae is being revised as a result of such studies which cover half a dozen genera including 19 species. A rapid method of staining genitalia has been evolved. The chaetotaxy of certain Lepidopterous larvae which are serious pests of gram, lucerne, tobacco, etc., has been studied with a view to preparing a key to the identification of the immature stages.

Control of insect pests by means of their natural enemies :

Although some work in Insect Parasitology has been going on in the Division of Entomology ever since its inception, a separate section of Parasitology was organised only in 1947.

(1) Studies on the effect of low temperature on the egg parasite, *Trichogramma evanescens minutum*, have shown that parasitised egg of *Corcyra*, 4 days after parasitisation can be safely stored for 15 days at 10°C.—12°C., and relative humidity 80-90 per cent. without impairing the viability, longevity, fecundity and sex ratio of the parasite. The longevity and fecundity of these parasites were significantly increased when fed with 10 per cent. solutions of glucose, fructose, maltose and sucrose, the maximum longevity of mated parasites was increased to about 5—7 times in males and 7—9 times in females. (2) Investigations on the ecological studies of potato tuber-moth parasite, *Bracon gelechiae*, have indicated that the fecundity of mated females was highest at 25°C. and 80 per cent. relative humidity, while at 70 per cent. and 90 per cent. relative humidities, it is very low. (3) The female of *Bracon gelechiae* exercises considerable choice in the selection of hosts and that the fecundity is not impaired if kept for long period without host.

Experiments on the biological control of the potato tuber-moth by the use of the exotic parasite, *Bracon gelechiae*, have given encouraging results. Large-scale releases of this parasite in potato godowns are being taken up. The technique for the propagation of *Stenobracon deesae*, a potential larval parasite of the sugarcane borers as well as the maize stem borer has been developed.

Biological control of sugarcane stem and root borers :

Trichogramma colonization field experiments reported in representative centres in the provinces of Bombay, Madras, Orissa and Bihar have confirmed our previous findings, viz., that when the outbreak of the sugarcane borers is large, *Trichogramma* is effective in reducing the pest population thus acting as an important factor of control.

Investigations in Insect Ecology and Toxicology :

(1) The effect of temperature on the susceptibility of insects to insecticide dusts has been further studied corroborating earlier findings with insecticide film. It has been found that the temperatures at which the insects are kept before the application of insecticide has a marked effect on their susceptibility.

(2) Investigations have been carried out on "specific susceptibility of HCN and the amount of HCN recovered from the insect after fumigation." The results will be shortly published.

(3) It has been found that the toxicity of DDT suspensions used as spray increases with the decrease in particle size upto a certain stage but further decrease in size, decreases the toxic effect. An explanation from this observation has been suggested.

DIVISION OF MYCOLOGY AND PLANT PATHOLOGY

The earliest important contributions from India on rusts and mucors were made by two army medical officers, Major A. Barelay and Dr. D. Cunningham and a genus of Mucorales, *Cunninghamella* was named after the latter. Systematic work of fungi, however, began in 1901 with the appointment of Dr. E. J. Butler as the Imperial Cryptogamic Botanist to the Government of India. Mycological work was started at the Agricultural Research Institute in 1905 by Dr. Butler as the Imperial Mycologist. Owing to the dearth of trained men in this branch of science and as the botany departments in various Universities were only just being started, Dr. Butler trained up young workers most of whom eventually took up work as Mycologists in the Provinces and States.

The first period (1905-36)

Studies on fungi :—In the initial stages the main lines of work were to collect diseased specimens and to study the symptomatology of the relatively more destructive diseases. Identification of the causal fungi was done as a matter of routine and much pioneer work was done on the taxonomy of fungi. Butler's "Fungi and Diseases in Plants" and Butler and Bisby's monograph entitled "Fungi of India" published in 1931 will be always remembered as most useful reference books. A supplement to the latter has been published by Mundkur in 1938. One of the earliest memoirs published by Butler was "The genus *Pythium* and some Chytridiales" wherein he classified the taxonomic position of this group which was in a state of confusion. Important contributions on other *Pythiums* were made also. *Pythium aphanidermatum*, first studied on ginger, papaya, etc., and later on cucurbits has been found to be a common organism doing damage to various crop plants. Until 1910 bud-rot of palms and rot of coconuts were believed to be due to *Bacterium coli*; it emerged from the work of Butler that the causal organism was a fungi, *Phytophthora palmivora* which is allied to *Pythium* sp. This work was universally recognised and wherever the palm diseases occur, this fungus has been found to be associated with the disease. Dastur discovered another important fungus, *Phytophthora parasitica*, and carried out intensive studies which led to a proper understanding of the diseases caused by this organism in India as also in some countries. *Fusarium udum*, the causal organism of wilt disease of pigeonpea has been fully studied. Stem-rot of rice caused by *Sclerotium oryzae* was thoroughly investigated by Shaw and later by Mundkur. Mitra studied the foot and root rot of cereals, particularly of wheat and barley, caused by *Helminthosporium* spp. and his contribution to our knowledge of this genus is recognised all over the world.

Butler and Hayman studied Indian wheat rusts and one of the earliest papers on the subject was published by them. Galloway published interesting observations on the soil fungi of India.

A Mycological Herbarium was started with the inception of the Institute and the Culture Collection came into existence in 1936. This is now the most comprehensive collection of fungi in India and perhaps one of the best in Asia.

Plant pathological investigations and control measures :—One of the earliest plant pathological problems investigated was the wilt disease of pigeonpea caused by *Fusarium udum*. A large number of varietal resistance trials were carried out and resistant varieties evolved in collaboration with the Division of Botany. Pathological investigations into the bud-rot of palms and rot of coconuts were conducted and the crop in the Godavari Delta was saved from

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total destruction by cutting off the tops of diseased palms and application of bordeaux mixture. Leaf spot diseases due to species of *Acrothecium*, *Helminthosporium*, *Alternaria* and *Cercospora* which cause great losses to economic crops were studied in detail and useful results were obtained for the control of the diseases. A number of varieties of wheat resistant to loose smut, a disease of major importance, were tested in collaboration with the Division of Botany.

Investigations into sugarcane diseases were also initiated by Butler. McRae carried out experiments on mosaic disease of sugarcane in order to assess losses due to the disease. He arrived at the conclusion that a 12 per cent. loss in weight occurs in 100 per cent. mosaic-infected crop of Co. 213, but added that wholly mosaic-infected cane does not exist in North Bihar outside the experimental plots. He found that the average amount of infection was only about 0.58 per cent. in the general crop. As no natural transmission is known to occur in Bihar, the loss in yield was estimated at 7 mds. in 10,000 mds. representing about 0.07 per cent. of the total crop, which he stated to be "insignificantly small". Intensive study of the mosaic virus, red-rot and smut diseases of sugarcane have, however, been undertaken since 1936 under a Scheme of the Indian Council of Agricultural Research.

The second period (1936-45)

New specimens and live cultures were added to the Herbarium (Cryptogamic India Orientalis) and to the Indian Type Culture Collection respectively. The number of Herbarium specimens rose to nearly 10,000 while the number of live cultures in the Collection increased from 104 in 1937 to 678 in 1945. A note-worthy feature of this period is that investigations on virus diseases, particularly those of potato and tomato crops, were initiated under a scheme financed by the Indian Council of agricultural Research.

Studies in Fungi :—The taxonomy of Indian smuts, rusts, *Fusarium* and other fungi, based on the study of specimens deposited in the Herbarium as well as collections made from all parts of India was revised. As a result, the number of smuts occurring in India was raised to 184 as compared to 99 known in 1930. Four new genera of rusts with 17 new species and 6 new combinations have been established. Intensive studies on the genus *Fusarium* were made by Padwick.

Plant pathological investigations and control measures.—1. *Wheat (Triticum vulgare)* :—Out of 207 varieties tested, 31 showed complete immunity and 23 very high resistance to *Ustilago tritici*. The fungus causing Karnal bunt was shown to be *Neovossia indica* (Mitra) Mundkur, and to be air-borne.

2. *Oat (Avena sativa)* :—It was established that not one but two smuts, *Ustilago avenae* and *U. kollerii* occur on oats in India. Concentrated formalin in the form of dry spray on the seed was found effective in controlling these smuts.

3. *Gram (Cicer arietinum)* :—A new species of *Fusarium*, which has been named *F. orthoceras* and a new fungus *Operculella Padwickii* have been isolated from wilted plants. High temperatures favour the development of *Fusarium* wilt and infection decreases if sowings are delayed to the last week of October or early November.

4. *Pigeonpea (Cajanus cajan)* :—Varietal resistance tests against wilt disease caused by *Fusarium udum* were carried out and the following varieties proved to be resistant : I.P. 80, I.P. 41, I.P. 51, I.P. 82 and hybrid cultures C5, C38, A-126-4-1, D-16-17-2 pt 12 and D333-4-22.

5. *Sugarcane (Saccharum officinarum)* :—The mosaic virus has been found to have 3 strains, viz., X, Y and Z. The virus remains ineffective even after passage through maize and jowar. Also the virus does not pass through L_3 Chamberland candles. Roguing and seed selection was found to materially help in controlling the disease at Pusa.

During 1938-40 there was a serious epidemic of red-rot disease in Eastern U.P. and North Bihar. The light-coloured strain of *Colletotrichum falcatum* isolated from the diseased canes was found to be more virulent than the dark coloured strain obtained in the pre-epidemic years. The red-rot infection can take place through the soil containing infected cane debris and through irrigation water. Secondary infection takes place through the nodal region of the cane.

In varietal resistance tests Co. 213, Co. 223, Co. 299, Co. 331, Co. 362, Co. 373, Co. 445, Co. 528 and Co. K.29 proved to be highly susceptible to red-rot; 28 varieties including 'Desi' canes (except *Pansahi*), *Saccharum spontaneum*, Co. 285, Co. 313, Co. 356 and Co. 419, Co. S.76 and B.O. 4 proved to be resistant. The other Co. canes occupy a position in between these.

Smutted canes and apparently healthy canes from smutted clumps harbour infection. A wild cane *Saccharum spontaneum* was successfully infected for the first time in India with sugarcane smut. Twenty two varieties proved to be highly resistant and 71 varieties moderately resistant to the smut. Roguing and seed selection have been found to control the disease effectively.

Virus diseases :

1. *Potato (Solanum tuberosum)* :—Observations made in potato tracts of Northern India showed that the commercial potato varieties are susceptible to the common virus diseases such as leaf-roll, and *Solanum* viruses 1 and 2.

The observations recorded for the first and second plains' crops show that under the field conditions masking of mosaic symptoms in the first crop is negligible as compared to the second crop and that masking of only negligible and *Bardetline* Mild Mosaic mainly occurs.

There is a gradual reduction in yield according to the severity of the mosaic diseases. The reduction involves the size, weight and number of tubers. The damage ranged from 25 per cent. in cases of mild infection to 97 per cent. in cases of severe infections. The affected plants mature earlier than the healthy ones.

Tests on differential hosts revealed the presence of strains of *Solanum virus* 1 and *Solanum viruses* 2, 3, 8.

2. *Tomato (Lycopersicum esculentum)* :—Tomato plantings were carried out on six different dates between July and November at intervals of 20 days. It was found that the incidence of severe types of diseases was highest in the first two sowings after which it began to decline. Occurrence of *Lycopersicum* virus 5 has been observed.

3. *Seed potato multiplication scheme* :—In June 1944 to raise production and meet immediate demands of cultivators a scheme was launched for the production and distribution of partially disease-free seed potatoes. In the first year of the scheme about 1350 mds. of seed potatoes were stored in the cold store for distribution in the plains.

4. *Seed potato certification scheme* :—Survey of potato-growing areas in Northern India showed low disease incidence of severe types of diseases and also

of aphids in the higher altitudes. The selection of virus-free tubers was, therefore, undertaken at the Central Seed Potato Certification Station, Kufri (Simla Hills) where conditions for masking of disease symptoms are least favourable. Some selections of apparently disease-free plants of the variety *Darjeeling Red Round* were made. Out of the material selected in the field, which appeared to be virus-free, one plant was selected in 1944 and further subjected to rigorous testing in the glasshouse for freedom from virus infection.

The present period 1945-48

The Division was re-organised into the sections of Taxonomy, Plant Pathology (Fungi) Plant Pathology (Bacteria), Plant Pathology (Virus) and Industrial Mycology. Important items of research of a fundamental nature, such as study of physiologic races of *Ustilago tritici*, antibiosis and study of the properties of purified preparations of certain viruses having direct or indirect bearing on the applied problems were taken up for investigation. Studies in the genus *Colletotrichum* were continued and a number of new hosts have been established. Also studies in the genus *Septoria*, *Pleosphaeropsis*, etc., were in progress. Nine new species and 21 new host records were established. The total number of specimens in the herbarium have come to 18,750 including 12 Exsiccati sets, while the number of cultures in the Collection which in 1947 had fallen to 625 exceeded 750 in 1949.

Plant pathological investigations and control measures :—1. Wheat (Triticum vulgare).—Investigations on loose smut of wheat (*Ustilago tritici*) have been conducted in cooperation with the Division of Botany for varietal resistance tests. Altogether 390 varieties were under test for this purpose. For the determination of physiologic races attempts are being made to make a selection out of 14 varieties of wheat representing 5 species of *Triticum* because the standard differential hosts do not properly seed under Indian conditions.

*Performance of seed from rust affected wheat plants :—*In 1947 the outbreak of a wheat rust epidemic resulted in considerable destruction of the crop in C.P. and there was not enough healthy plump grain for seed for the next year's sowings. Altogether 187 samples of seed were examined for germination purposes and 139 were recommended as suitable for seed purposes, as they showed germination percentage of over 70. In order to make up for the poor germination it has been suggested that the number of seed per unit area be increased for sowing purposes and it has been shown by experiments that the yield from the crop raised from rust affected plant seed is similar to that obtained from seeds from healthy plants.

*2. Oats (Avena sativa) :—Leave spot (Helminthosporium avenae) :—*Primary infection increases with fall in temperature and early sown plants show lower infection as compared to the late sown. Two wild grasses, *Phalaris minor* and *Avena fatua* have been found to be collateral hosts. The disease has also been observed on volunteer plants of oat during August-November. Seed treatment with Agrosan-GN successfully controlled primary infection.

*3. Pigeonpea (Cajanus cajan) :—*Out of 91 varieties tested for their resistance to wilt, some varieties such as N.P. 90, N.P. 41, N.P. 80, Co. 15 and crosses D.16-17-2 pt 3 and D-333-4-22 appear to be resistant.

*Antibiosis :—*The percentage of infection by *Fusarium udum* the casual agent of pigeonpea wilt in the sterilized soil has been shown to be much greater than in the unsterilized soil. Indication has been obtained that the activity of

Fusarium udum in unsterilized soils is suppressed by the activity of the associated microflora of which two isolates of bacteria which have been identified to belong to *Bacillus subtilis* group are important. Relative colonisation of straw by the soil fungi and bacteria during the growth period of pigeonpea plant shows considerable variation. This is noteworthy in view of the fact that it indicates likely correlation between abundance of some of the organisms and the reduction in the incidence of pigeonpea wilt disease. The reduction of *Aspergillus terreus*, *Aspergillus niger* and *Bacillus subtilis* during the month of November and their subsequent low level till the end of the cropping season corresponds to the high incidence of disease from November to February. The inhibition has been shown to be due to the metabolic products of the bacteria concerned and not due to any change in reaction of the medium. Inhibition of germination of *Fusarium udum* spores and subsequent abnormal morphological changes in the germ tubes serve as an indicator of antibiotic substance. The toxic principle which is thermostable is partly held back by L_3 Chamberland candles.

4. *Gram (Cicer arietinum)* :—Isolations made from a large number of wilted gram plants yielded species of *Fusarium*, *Rhizoctonia solani*, *R. bataticola* and *Operculella Padwickii* but in pot experiments typical wilt was produced only with *Fusarium orthoceras*.

Rust (Uromyces ciceris-arietini (Gron.) Jacz.) :—Only the uredial and telial stages are known. Telia are rare but the formation could be induced by increasing the amount of carbohydrate in detached leaf cultures. *Trigonella polycerata*, a leguminous weed, was found infected by this rust in February, i.e., earlier than gram. This weed is widely distributed in the hills up to an elevation of 6000 ft.

5. *Lentil (Lens esculenta) Rust (Uromyces fabae) (Pers de Bary)* :—The life history was studied and it was shown that over-summering teliospores on plant debris or mixed with the seed cause fresh infections. Therefore, it was suggested that burning the plant debris after harvest and treating the seed with an organo-mercury fungicide would eliminate the source of infection and control the rust considerably.

Wilt (Fusarium sp.) :—Low soil moisture, good aeration and temperature between 23°—31°C. are favourable for the disease.

6. *Linseed (Linum usitatissimum) Rust (Melampsora lini (Pers.) Lev.)* :—Varieties of linseed, flax and their crosses were tested for seedling and adult resistance against a mixture of four Indian physiologic races of the rust. Out of 124 varieties tested in the first year 74, and in the second year 70, varieties proved resistant to the disease both in the seedling and adult stages.

7. *Safflower (Carthamus tinctorius L.) Rust (Puccinia carthami (Hutz.) Corda)* :—The life history of this brachy-form, autoecious rust which is found on *C. tinctorius*, the cultivated safflower, and *C. oxyacantha*, the wild species, was studied. It was found that over-summering teliospores from crop debris or from wild safflower bring about fresh infections in the following season.

8. *Pea (Pisum sativum) Wilt (Fusarium oxysporum Schlecht.)* :—The disease is favoured by sandy soils. Addition of farmyard manure reduced disease incidence. Indications of 4 physiologic races were obtained.

9. *Potato (Solanum tuberosum)* :—Early blight infections are not carried over on the tubers obtained from the infected crop.

Seventy-eight potato varieties and hybrids were found to be resistant to late blight (*Phytophthora infestans*).

The *Phytophthora* isolated from diseased tubers in 1945 and 1946 at Kufri is a new species and has been named *P. himalayensis* Dastur., *P. parasitica* Dastur, causes a leaf rot in potato and generally occurs a month earlier than *P. infestans*.

Phytophthora infestans from Simla was brought into culture and is being maintained on Leonin's agar and Maltose-peptone carrot extract agar.

10. *Sugarcane* (*Saccharum officinarum* L) Red Rot (*Collectotrichum falcatum* Went) :—Out of 79 and 94 varieties tested during 1946-47 and 1947-48 respectively, only six cane varieties including spontaneums, viz., Co. 349, Katha, Chunnee, *Saccharum spontaneum* (Burma), *Saccharum spontaneum* (Java) and *Saccharum spontaneum* (Coimbatore), proved highly resistant and 73 moderately resistant.

Smut (*stilago scitaminea* Syd.) :—During 1946-48 the number of varieties tested in each year was 83 and 93 respectively. These cane varieties were tested at Karnal and Delhi by infecting the sets with viable smut spores at planting time. Out of these, 43 varieties showed less than 15 per cent. infection and could be regarded as resistant and 32 as moderately resistant. *Saccharum spontaneum* obtained from Coimbatore was found to be highly susceptible, but one obtained from Java did not take infection.

11. *Fungicidal seed treatment* :—Tests were conducted with Ceresan, Agrosan-GN, Barbak, Spergon, Copper carbonate and sulphur. In maize Ceresan and Agrosan showed increase in germination by 10 and 9 per cent. respectively. In *Jowar* and *bajra* an increase of 16 and 15 per cent. respectively was obtained with Agrosan-GN. Increase in yield in maize on the basis of cob-weight was 13.5 per cent. with Agrosan-GN. During the *rabi* season seed treatment of oats with Ceresan gave 10.2 per cent. higher yield. Incidence of covered smut of oats was nil in the crop raised from inoculated seed treated with Ceresan, Aagano and Agrosan-GN, whereas in the untreated lot the disease incidence was as high as 17 per cent. Seed treatment of barley with Ceresan gave an increased yield of 8.5 per cent. Tests conducted at Kufri have shown the effectiveness of Perenox and against late blight of potato.

12. *Assessment of damage due to diseases* :—In the case of late blight of potato, it was observed that 95-100 per cent. infection of the leaf area brought about a reduction of 50 per cent. in yield, whereas 25-50 per cent. infection of the leaf area reduced the yield by 21 per cent.

In the case of Agra Local wheat percentage reduction in yield with 90 per cent. and 75 per cent. black rust infection was found to be 55.6 and 26.6 respectively, whereas in N.P. 4 reduction in yield was 38.7 per cent. with 90 per cent. infection and 20 per cent. with 50 per cent. infection.

Observations recorded on the previous year's ratoon crop of Co. 312 with a view to assess the losses due to sugarcane smut showed that the average weight of millable canes per smutted clump was 1.63 lbs. as against 2.64 lbs. for healthy clump in the control plot.

Virus diseases of plants :

1. *Potato* (*Solanum tuberosum*) :—*Solanum virus-6* was recovered from potato plants of Phulwa variety. Potato plants of varieties *Darjeeling Red Round* and *Tasmanian Bismark* developed severe necrotic symptoms on the

foliage. The causal virus which could be easily transmitted by *Bemisia tabaci* was identified as *Nicotiana virus-10*.

2. *Tomato (Lycopersicum esculentum)* :—Tomato plants affected by a latent virus were often found to act as symptomless carriers. The infected plants developed intracellular inclusion and cubical crystals. Leafcurl of tomato was found to be caused by *Nicotiana virus-10*. It has been indicated that the virulence of this virus is adversely affected after passage through *Capsicum annum*. Veinal necrosis in tomato has been shown to be caused by a mixture of *Solanum viruses 1 and 2*.

3. *Sunnhemp (Crotalaria juncea)* :—The virus causing mosaic disease of sunnhemp was purified and obtained in crystalline form. Properties of the purified preparations as also the ultraviolet absorption spectra of the virus were studied. Phyllody of sunnhemp appears to be caused jointly by sunnhemp mosaic and tobacco leafcurl viruses.

4. *Bottlegourd (Lagenaria leucantha)* :—A new strain of bottlegourd mosaic virus has been described and designated as 2C. The virus has a restricted host range and is carried symptomlessly in *Datura stramonium* and certain other hosts. The virus has also been found to be carried at the point of inoculation but fails to move out of the inoculated point. The properties of the virus have been fully studied.

A seed transmitted virus disease of lettuce has been recorded.

5. *Seed potato certification scheme* :—After repeated selection and tests in the insect-proof glasshouse, virus-free material of seed potatoes of varieties *Darjeeling Red Round* and *Up-to-date* was established and multiplied at higher altitudes. The material was handed over to the Central Potato Research Institute for further multiplication.

6. *Seed Potato multiplication scheme* :—Partially disease-free seed potato material was distributed to growers through the Provincial and State Agricultural Departments in connection with the "Grow More Food" campaign. In 1947-48, 3026 maunds of potato seed were distributed. Their performance was very satisfactory from the point of view of disease incidence and outturn. As reported by the U.P. Department of Agriculture the disease incidence in the crop raised from such seeds varied from 1-2 per cent., while it was 50-75 per cent. in crop raised from seed obtained from commercial sources. Yield per acre from the selected seed supplied under this scheme was nearly 250 maunds as against 125 maunds per acre obtained from crops raised from commercial seed. A record yield of 427 maunds per acre was reported by the U.P. Department of Agriculture from seed supplied by the Division.

DIVISION OF AGRICULTURAL ENGINEERING

The Division of Agricultural Engineering was established only towards the end of 1945. Its activities therefore fall within the third of the periods into which the summaries of work of other Divisions are grouped. At present the Division has no buildings or workshop of its own and is temporarily housed in the Division of Agronomy.

Prior to the establishment of the Division, some work in the field of Agricultural Engineering was done by the staff of the Agronomy Division. Thus in 1943-44, a useful collection of ploughs from various parts of India

was made to determine the draft required for operation of these ploughs and also to study their general characteristics.

From 1920 onwards, data and costs of operation of steam tackles for ploughing operations, and later, from 1934 similar data for operation of tractors and power implements were collected and published in the annual reports. These figures have been used as a guide of costs in mechanical farming.

The work of the Division of Agricultural Engineering may be broadly classified as follows :—

1. Maintenance, repair and operation of all tractors and machines of other Divisions of the Institute.
2. Lectures and practical classes to the Post Graduate students of the Division of Agronomy.
3. Advisory work and technical reference required by the public and departments of Government.
4. Research work on design and development of agricultural machines and implements and testing and trial of tractors and implements from abroad.

Mechanised farming :

From the year 1945, gradually the extent of mechanisation of the I.A.R.I. farms at Delhi and Karnal has been on the increase. During 1945-46 and 1946-47, the mechanisation was limited to the preparation of seed beds by power driven ploughs, discs and harrows. During these years, a part of the grain crop was threshed by stationary machines both at Delhi and Karnal. During 1948-49, the entire crops were machine threshed and a modern self propelled combine was in operation during 1949 harvest at Delhi. Mechanisation of the farm transport, dung handling and manure distribution in the fields are now being planned. With the experience gained in the above advice is being given to State Governments and the public about selection of mechanical farm equipment. The importance of this subject can be realised, as at present some of the State Governments are confronted with the task of mechanical cultivation in the area reclaimed by the Central Tractor Organisation.

Farm drainage :

To overcome the effects of seepage water in irrigated farms and avoid alkali formation and consequent damage to crops, a proposal and plans for the surface drainage of the Agronomy farm and tile drainage of the Botanical farm at Delhi were prepared. No such work of sub-surface drainage has been reported from any part of India. The purpose of this experiment is also to assess the costs of tile drainage and estimate the benefits in form of crop yields. This subject is of particular interest at Delhi, as it has been observed that the level of the sub-surface water has been steadily raising in the past few years. This is also a subject of importance for the new river valley projects of India, where large acres of land will be brought under irrigation, which may need facilities of drainage, if it has to be kept under crops for a long number of years.

Land reclamation :

During 1946-47 and 1947-48, guidance was given by this Division for the Kans Control Scheme in Bhopal State, where deep ploughing by heavy

tractors was adopted for eradication of deep rooted kans grass. 12" deep ploughing for two continuous years and a start with a leguminous crop for rebuilding soil fertility were most suitable and Kans could be practically eradicated at the end of two years in the Bhopal area by the above method. These experiments and the results are bound to be of great value in the large areas of land now under reclamation by the Central Tractor Organisation. Mechanical treatment of the soil is important if a recurring growth of Kans is to be avoided, in the areas ploughed by heavy tractors for reclamation of weed infested land.

Tractor Operation Data :

From the actual field operation of different makes of tractors both of the wheel type and track type some burning kerosene and some using High Speed Diesel Oil, data have been compiled and costs calculated per hour and per acre of operation for different farm operations such as ploughing, disking, cultivating and harvesting. This information is also used as a basis in advising farmers who contemplate mechanised farming in the near future.

One of the factors which is delaying mechanised agriculture, in part of India, where it may be the only available method, is the absence of adequate knowledge of costs of operation of farm machines. Figures collected in the U.S.A. and U.K. are not likely to be of value in India, where the economic conditions are entirely different. Variation in costs of fuel oil and labour charges in different parts of the country have to be considered in such calculation. Standard procedures for calculation of tractor costs and operating data which are applicable to owner-operator conditions, have been adopted in the figures published by the I.A.R.I.

The tractor that decides is whether mechanical farming or bullock farming is cheaper of the two. In co-operation with the Division of Agronomy, I.A.R.I., costs of similar farm operations by bullock power and mechanised farming are now being worked out.

GARDEN TRACTORS IN INDIAN AGRICULTURE

Test and trials have been conducted on small horse power walking-type of tractors fitted with air-cooled petrol engines, to determine their practical and economic possibilities under Indian conditions of farming. Due to slow speed, high cost of operation and certain mechanical defects, generally, walking tractors of the above type were found uneconomic under Indian conditions for arable farming.

In the industrialised countries of the West, Garden tractors or tractors below 13 H.P. are used in large numbers on farms of less than 40 acres. These tractors are used for light farm operations except ploughing. The above tests have shown that Garden tractors do not seem to be economical.

The Jeep for agricultural operations :

The jeep, an army vehicle, manufactured by the Willy's Corporation and Ford Motor Co. of America, was sold to the public in India in 1946-47 and there was considerable interest in the country in the jeep as a tractor and truck for farm use. Experiments were conducted in the Institute and the jeep was found most suitable for transport of farm produce with a trailer at its back. The lowest land speed being too high for most cultural operations and its turning radius being large it was found to be not generally suitable for field operations in small farms. The clearance below the chassis being low and with wheels set, it was also not suitable for row crop cultivation.

From the tests it revealed that on a farm using a tractor the jeep can pull one of the lighter and faster operating implements where plot size is large while the tractor is used for heavier types, thus speeding up field operations. The jeep can serve as a utility vehicle for very light field operations and general transport work.

The Twin Country Plough.

In an original research project recently carried out by this Division to study the economic and practical possibilities of country plough operation by a low horse power tractor in lieu of bullocks it was discovered that the draught of two country ploughs suitably coupled together fell far short of double that required for a single plough and it was immediately decided upon to investigate the possibility of designing a double desi plough capable of being operated by a single average pair of bullocks.

The plough as designed is simple in construction and consists of the bottoms of two standard local desi ploughs suitably coupled together by means of an angle iron frame work and pulled by a single central beam. The ploughs are so spaced in relation to each other that identical furrows are cut and carry out in one operation similar work as would be performed by two operations with a single standard plough.

The plough is comparatively light, its weight being 37 lbs. as against the 60 lbs. of a single desi plough ; thus an average ploughman can easily lift and carry it as required, for ordinary operational purposes. The draft is, tolerable, being in hard dry land, ploughing 5" deep, 254 lbs., while that of a single similar plough under similar conditions was 157 lbs. The draft of a single 'Victory' bullock drawn, soil inverting plough under average conditions varies between 320 and 400 lbs.

The merits of the plough are obvious. Bullocks are generally so far as ploughing is concerned are under-loaded, and, based on observations made on bullocks when operating 'Victory' plough and single desi ploughs, there is a little doubt that this new plough is capable of being operated by a single pair without undue extra effort. Assuming this, its daily output will be practically double. Taking an extreme where bullocks are capable of operating this plough for only half the usual daily working period the outturn of work will be similar and the cultivator's extra time will be available for relaxation of alternative work. Quality or regularity of ploughing must automatically be improved. Seasoned ploughmen who have used plough state that in operation it is easier and less tiresome to handle due to its 'Stableness' when in work. When in production it is estimated that its cost will not exceed Rs. 45/- when compared with the present cost of a single desi plough at Rs. 30/-; a feature of importance for it is the cultivator and not the landlord who has to purchase implements.

It is simple in construction and thus easily repaired or even constructed by the village blacksmith or carpenter and may well prove to be of great value in the effort being made today to increase food production, and at the same time easing and improving the work of the cultivator.

Compost production :

A rotary screen has been designed and developed in this Division for purposes of separating rotted manure from brickbats, stones, or glass pieces, which are found in the refuse dumps of our large cities. This is worked by a 1.5 H.P. petrol engine and has a capacity to handle 120-150 maunds of refuse per hour and will yield on an average 80-100 maund of manure per hour.

After first trials of the working of the proto-type machine, a more comprehensive machine which will separate the manure and as well load the same into trucks or carts has been designed and this is awaiting field trials. The new screen-cum-elevator will again be worked with a tractor mounted manure loader at the Badli Dump Yards (Delhi). Labour saving devices are necessary not only to reduce costs of operation but to counteract labour shortages and an attempt is being made to achieve this.

Harvesting Machines :

- (a) The labour requirements in harvesting the small grain crops are high and need machines which will release bullocks for hot wheather ploughing and other operations. A bullock drawn mowing machine from the U.S.A. was used in the I.A.R.I. farm during the harvest of 1949. A buncher attachment was locally added to the machine which saved considerable labour in collecting the grain. A side conveyor to deposit the cut grain to one side is however the ideal. A horse-drawn binder with suitable modifications to suit the drafts of bullocks is to be tried out in the near future.
- (b) An engine operated reaping machine has been designed and the first working model of the same has been built. It is worked by a 1.5 H.P. engine and can cut 4 to 5 acres of standing grain in a day of 10 hours, consuming 1.25 gallons of petrol. The driving arrangement of the land wheels was found to be defective and experiments are being continued. A model of hand operated reaper for small grain crops as wheat and rice has also been built. All these machines need further work.
- (c) A fan below the riddles has been added to an Indian built threshing machine, with a view to produce, clean and graded grain in one operation of the threshing machine. This also needs further investigation, as regards speed and correct location of the fan and its chute.
- (d) Two threshing machines, which are suitable for cooperative village use, have been recently secured from Denmark. They are entirely built of wood, except for a few steel parts. Their working found satisfactory but the structure was weak that it needed frequent repairs. Further work to modify this machine for local fabrication and use will be taken up.
- (e) During the harvest of 1949, a self-propelled combined harvester thresher was tried out in the I.A.R.I. farm. While its working on wheat and oats, both as a stationary and also as a field machine was found satisfactory, certain modifications are needed in its design to effect the saving and collection of straw. Economics of its operation will be studied during the next harvesting season.

Harvesting and threshing machines from abroad for small grain crops like rice, wheat, oats and barley have been tried in the I.A.R.I. farms. The bullock reapers and Danish Threshers have been found to be suitable for our conditions.

Cultural experiments :

A fertilizer placement machine, which can place chemical fertilizer on either side of seeds planted in rows, has been recently secured. In co-operation with the Division of Agronomy, experiments to determine optimum fertilizer placement, for most economic crop yields will be undertaken. Some

modifications to the machine to suit the conditions required in the experiment are now being made.

It is likely that chemical fertilizers will be used in Indian Agriculture in larger quantities in the very near future. Hence machines for the correct placement of the fertilizer to get best yields and for economy in the use of the fertilizer are important. Designs are being worked at present, to devise smaller machines of the same type for bullock operation.

Workshop :

The workshop has not yet been built. Without it research work as also the work of servicing and maintenance of farm machinery and implements on which their life and efficiency as also the efficiency and timeliness of cultural operations which determine to a great extent the yield of crop depend cannot be done at all efficiently.

SUMMARY OF MAIN RESULTS OF RESEARCH (1948-49)

AGRONOMY

MANURES AND FERTILIZERS

Nitrogenous manures and fertilizers : Russell Experiment No. 3.—This experiment started in 1944-45 with the object of studying the relative uptake of nitrogen from green manures, compost, F.Y.M., cakes and ammonium sulphate by wheat crop was continued. The crop yield in this experiment has been adversely affected in previous years by such factors as weather, rust, lodging etc. In the current years, of all the treatments green manuring with sunnhemp gave the best response.

Fertility building experiments:—This has been a very fruitful line of investigation and several experiments are in progress.

Phosphatic manuring of legumes :—(a) The effect of the inclusion of pea in the maize-wheat rotation was studied. The fertilizers applied were 60 lbs. N either as ammonium sulphate or F.Y.M. or cake plus 100 lbs. P_2O_5 plus 100 lbs. K_2O . The results show that wheat in the rotation with a legume gave higher yield than without it. The response to different sources of nitrogen was in the order ammonium sulphate|castor cake|F.Y.M.

(b) Application of different doses of phosphate alone and in combination with nitrogen or potash to the *berseem* crop in the rotation *berseem* (manured)—fallow—wheat—fallow—wheat showed that the residual response on wheat yield was better indicated with 60 lbs. P_2O_5 than with 120 lbs. P_2O_5 |acre.

(c) Experiment on manuring of *berseem* with graded doses of phosphate showed that best fodder yields were obtained with a dose of 64 lbs. P_2O_5 |acre whether applied as super or F.Y.M. or a combination of the two.

(d) Experiment to determine the comparative response in fodder yield of *berseem* with different forms of phosphate showed that ammophos proved to the best.

(e) Other clovers e.g. *Senji*, *Mathra* and *Shaftal* showed a response similar to *berseem* with phosphatic manuring.

Placement of fertilizers :—With peas phosphatic fertilizer placed at 4½" depth gave better response than either broadcast with or placement at 3½" depth.

Green manuring experiment :—Highest yield of succeeding wheat crop was obtained from plots where green manure was grown and buried *in situ*, as compared with green manure grown in another field but buried in the experimental plots, or grown in another field but buried in the experimental plots for composting, or no green manure treatment.

CULTURAL EXPERIMENTS

Gram wilt :—An experiment on the date of sowing, depth of seeding and spacing of rows as influencing incidence of gram wilt disease and yield of crops showed that mid-November sowing gave more yield than the October or early December sowing. Sowing at 2½" depth gave greater outturn of grain/acre and lower incidence of wilt. 12 inches spacing between the rows yielded better than either 9 inches or 18 inches.

In potatoes for the second year *Phulwa* variety gave better outturn of potato by spacing the seed at 9 inches. Planting tubers having lesser diameter than 1 inch lowered the yield by about 14 per cent.

Seed rate :—An experiment to determine the optimum seed rate requirements of wheat on medium loam soils with an assured supply of water showed that high rate (65, 80 or 95 lbs./acre) gave significantly greater yield of crop over the low rate (50 lbs./acre).

VARIETAL TRIALS

Field trials to test the performance of new cane varieties Co. 537, Co. 620, Co. 621 and Co. 622 against Standard Varieties of Co. 312, Co. 421 and Co. 453 showed that though Co. 312 out-yielded others, Co. 537 and Co. 622 indicated promise.

Amongst the new wheat varieties NP 720 yielded 21.5 mds., compared to 20.5 mds. of NP 165 and 17.8 mds. of C 518. Other wheats with comparable yields to NP 165 are NP 775 and NP 733. The trials will have to be repeated before any conclusions are drawn regarding the relative merit of the varieties.

New potato hybrids H 209 and H 208 exhibited better outturn than *Phulwa*, *Gola* or *Khara* varieties. Here again it will be necessary to repeat the trials.

MIXED FARMING UNITS AND CULTIVATOR'S HOLDINGS

The experiments on 8-acre mixed farming units were continued. Different intensities of green manuring supplement the F.Y.M. available from work cattle to the extent of green manuring 50 per cent and 60 per cent. of the *rabi* cereal area. Eight years' data from other experiments revealed that with inadequate availability of F.Y.M. the practice of green manuring should be adopted to keep up high level of soil fertility and remuneratively augment the cereal, feed, fodder, roughage and cash crop yields. Experiments on five 6-acre cultivator's holdings to compare the relative merits of alternate crop rotations for maintaining soil fertility with and without application of phosphates to the legumes in the rotation were in progress for the second year.

GRASSES AND LEGUMES (AGROSTOLOGY)

Grasses and legumes :—Eleven more grasses and seventeen more legumes were added to the previous year's collection of 60 grasses and 16 legumes.

Phalaris tuberosa, *Pennisetum orientale* and *Panicum repens* showed superior performance in the first year. *Setaria palmaefolia*, a highly nutritious irrigated fodder grass responded to a fertilizer mixture of 20 lbs. N and 40 lbs. P_2O_5 /acre. Observations on various clovers, vetches, medics and lupins were recorded. Experiments with twenty-three seed mixtures were in progress. Collaborative trials on grasses and legumes have been taken up in different States based on the experimental work in progress at the Institute for the past 2 years.

Ley :—Three years' Rhodes grass and lucerne ley was ploughed down and studies on residual response of maize and wheat in rotation were taken up. Ley plots treated with superphosphate alone or in combination with nitrogen indicated superior yield responses.

ANIMAL HUSBANDRY AND MANAGEMENT

The Institute maintains two pedigree herds, the Sahiwal at Delhi and the Tharparkar at Karnal. The former has dairy merit and the latter is a dual purpose animal. It was noticed that shortage in legume fodder adversely affected the health of the milch stock milked four times during the day. Temporary unavoidable stoppage of mineral feed had also bad reaction on the health of animals.

Milk yield and four times milking :—In the Sahiwal herd 66.5 per cent. of the cows remained in milk. The wet and overall averages of the herd were 20.1 lbs. and 13.4 lbs. per cow per day respectively. Cow Tamili broke her previous record of 12384 lbs. by yielding 13,004 lbs. in a 10-months lactation. Over 42.1 per cent. of the cows in the herd gave over 6,000 lbs. lactation yield. Inlakhir, a first calver yielded over 13,841 lbs. of milk in a continuous period of 640 days at the average rate of 21.6 lbs per day. The milking average of the Tharparkar herd was 18.6 lbs. and overall average 12.0 lbs. per cow per day. There occurred a set-back to milk yield due to severe incidence of Foot and Mouth disease twice during the year. Four-times milking did not cause any set-back in the health of the stock. It was observed that animals milked four times had better persistence and usually completed 10 months lactation unlike those on reduced number of milkings.

Selection and line breeding :—Twelve bulls were maintained at each of the research centres. In the Sahiwal herd, the bull Asoka possessing great prepotency for milk, continued to serve as the main herd bull. The progenies of bull Tikka in the Tharparkar herd further indicated high prepotency for milk.

Early maturity experiment :—The average age at calving of Sahiwal heifers was 2 years 7 months and 14 days, the normal being $3\frac{1}{4}$ years. In the Tharparkar herd the age at calving was 2 years 8 months and 10 days while ordinarily Tharparkar heifers calve at 3 years and 10 months, a saving in cost of maintaining them for a period exceeding a year.

Growth rate :—The average growth rate of 20 female calves of the Sahiwal herd was 1.0 lbs. per day. Of the Tharparkar herd the rate of growth during the first six months was 0.88 and 0.77 lbs. per day.

Precalving milking :—The procedure of precalving milking was further standardised; average period was 10 days in adult cows and 15 days in heifers. Animals in poor state of health reacted adversely to precalving milking.

BOTANY

BREEDING FOR DISEASE RESISTANCE

Problem of wheat rust :—The main breeding work in relation to wheat rust has been at Simla under a scheme financed by the Indian Council of Agricultural Research; the scope of this is limited to the hill wheats on the basis of Dr. Mehta's finding that the hills are the foci for the over-summering of the rusts. During the year work was continued on the double cross, made on a large scale, to combine resistance to the three rusts with desirable agronomic characters. The large number of hybrid cultures were in the F₅ generation and there were indications that some of them are approaching purity in respect of the major distinguishing characters. Selections were made in these for next year's work. Whilst hardly any plant was completely free from rust, a sufficient number of them had the merest trace of one or two rusts and from the practical point of view appeared to be very desirable. Besides these, wheat strains resistant separately to the physiologic races of the three rusts occurring in India have been built up during the course of the breeding work. These strains were put under small-scale trials at several places in the hills to see whether any of them could be of immediate use to the farmer until wheats combining resistance to all the three rusts could be developed. Many of the strains have been found to retain their resistance to the particular rust against which they were bred, and under Simla conditions they gave high yields, comparing favourably with the local hill wheats in this respect. A few strains from the black rust series of crosses appear to be promising and will be tried further.

Rust-resistant linseeds :—Breeding and testing linseed strains for resistance to rust (*Melampsora lini*) were continued. At Delhi, 78 out of a total of 101 strains tested in collaboration with the Mycology Division proved to be immune in the adult stage to the four physiological races of the rust fungus so far observed in India. The results of seedling resistance were more or less in agreement with the adult resistance tests mentioned above. At Karnal, under conditions of natural infection, only four out of 101 strains showed infection. Preliminary trials with 35 of the above strains in some of the important linseed-growing tracts showed that in East Punjab and West Bengal some of the strains outyielded the best local variety by about 50-100 per cent. Chemical analysis has shown that a few of the promising strains have higher oil content than the existing commercial varieties.

TRIALS OF NEWLY EVOLVED STRAINS OF FOOD CROPS

Wheat trials :—Twelve recently evolved N.P. strains of wheat were again under trial at 26 different stations representing the important wheat growing tracts of India. The results indicated that as in the 2 previous years some of the N.P. strains did very well at these places. Some of these strains like N.P. 718, 737 and 745 were resistant to brown or yellow rust, whilst N.P. 710 and 715 showed considerable tolerance to black rust.

In an experiment on the response of 5 varieties of wheat and a mixture of all these to 3 levels of manuring in addition to no-manure treatment, the observations made last year that the varieties do not respond differentially to the manurial treatments was confirmed. Each manurial treatment, however, did have a significant effect on the yields of varieties.

Potato trials :—Six improved potato hybrids higher in yield and earlier in maturity than the main commercial varieties of the plains and also possessing tubers of good shape and size were sent for trials in the plains of Bihar,

U.P. and East Punjab. The yields of the four more promising hybrids out of these and the three commercial varieties of the plains of India obtained at Delhi are indicated below:—

Hybrid or Local variety	Hyb. 45	Hyb.208	Hyb. 209	Hyb. 610	Controls		
					Phulwa	Gola	Dari Red Round
Yield in lb. per 10 0 plants	135.1	26.2	122.5	125.3	118.1	101.5	115.7

STUDY OF HYBRID VIGOUR AND THE POSSIBILITY OF ITS EXPLOITATION IN AGRICULTURE

Maize :—One hundred and one indigenous and 20 exotic varieties obtained from U.S.A., Australia and Africa were grown and studied for their vigour, maturity, height, number of cobs per plant and ear and kernel characters and 29 Indian and 6 foreign varieties were selected for a preliminary yield trial in the next season. Eleven double crosses received from U.S.A., South Africa and Australia were studied in observation plots. Nearly 700 inbred lines were further selfed and studies on the extent of homozygosity before crossing the inbreds, comparative merits of selfing and sibbing etc. were continued.

STUDY OF THE WILD RELATIVES OF CROP PLANTS AND THEIR UTILIZATION FOR BREEDING SUPERIOR CROP PLANTS

Tomato :—Six new strains of tomato selected from the cross *Lycopersicon esculentum* x *L. pimpinellifolium* and found to be early in maturity with high vitamin C and sugar, high yield and flavour, were finally selected for trials in the states. A collection of new genetic material including wild species received from the U.K. was studied in detail for its breeding possibilities.

Sesamum :—Work on the breeding of strains of sesame resistant to phyllody and to a caterpillar pest was continued and the progeny of the back-cross *Sesamum indicatum* x *S. orientale* was studied with regard to its cytological behaviour, morphological characters and disease incidence and selections showing greater vigour and hardy quality of the parent were made for further study.

POLYPLOIDY AS A METHOD OF CROP IMPROVEMENT AND TRIALS OF INDUCED POLYPLOIDS

The colchicine-induced autotetraploids of *Brassica* Spp., gram chilli and sesame were further studied with regard to their seed fertility and other agronomic characters for evolving superior tetraploid strains. The reduced fertility in gram, chilli and sesame was sought to be overcome by intervarietal hybridization. Autotetraploids were obtained in 6 varieties of linseed. Studies on the breeding behaviour of the tetraploid plants of *taramira* showed that they do not breed true to chromosome number.

OTHER LINES OF CYTO-GENETICAL INVESTIGATIONS

Additional lines of cytogenetical research have been initiated very recently for the study of interspecific and intergeneric hybrids of wheat and related species and genera and also the investigation of techniques for a fundamental study of the structure and composition of chromosomes.

PHYSIOLOGICAL INVESTIGATIONS

Drought resistance in wheat :—Eleven varieties of wheat were tested for drought resistance both on a field scale and in pot culture. An analysis of the developmental observations indicated that yield under restricted soil moisture supply was particularly correlated with ear number (tillering capacity), grain number and 1,000—grain weight, either singly or in combination, according to the rate of production and mortality of tillers as determined by other environmental conditions. For instance, the grain yield at Pusa was correlated with grain number and 1,000—grain weight whereas at Delhi and Karnal it was particularly correlated with ear number.

Physiological analysis of yield :—A detailed analysis of the relation of increase in the total dry matter of the wheat plant (main shoot only) after ear emergence to grain formation revealed that almost the whole of the grain weight was accounted for by the net assimilation occurring after ear emergence. Under normal conditions varietal differences as regards grain number and grain size were not determined by net assimilation during post-ear-emergence period but under conditions which restricted photosynthesis these characters appeared to be affected according to the relative contributions made by photosynthesis in the different organs to net assimilation ; as such the possibility was indicated of interpreting along these lines the differential response of varieties to at least some adverse environmental conditions.

Effect of light and temperature on flowering :—A microdissection study of the differentiation and further growth of the ear and stem in wheat indicated that variation in day length or temperature did not as much influence the former as the latter phase. This study indicated the possibility of raising more than one generation of wheat in a year and thus hastening the breeding programme.

Plant hormones :—Spraying with the weedicide " methoxone " at the rate of 1 pound per acre proved as effective as and more economical than weeding with the *khurpi*, in improving the yield of wheat.

Nutrient uptake in relation to growth and yield :—A preliminary study of the uptake of nitrogen by three varieties of wheat indicated that one variety absorbed appreciably greater amount of nitrogen than the other two, although it did not differ as regards yield from them. This difference could be accounted for by its higher tillering capacity (although ear number did not increase proportionately) and grain number per ear.

ECONOMIC BOTANY AND PLANT INTRODUCTION

Plant Introduction :—Localities round about Bhowali and Almora in the Kumaon hills were surveyed and material of several perennial grasses, pepper-mint, wild yam, ginger and legumes was collected.

Nearly 500 seed samples mostly of grasses, legumes, new improved varieties of various crop plants and other breeding material were obtained from the foreign countries. They included wheat varieties from the U.S.A., Australia, fodder and forage legumes and grasses from Brazil and Uruguay, sweet potatoes and sunflower from South Africa and linseed and flax from Sweden. The new material was grown at Delhi and some of it also at Pusa and Coimbatore and observations on its performance recorded. The study of root crops, which form an excellent subsidiary food, received close attention. A collection of 21 exotic and 29 indigenous varieties of sweet potatoes was

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under observation and 2 varieties from China, Tse-Shin-Tun and FA 17 and 3 varieties from the U.S.A., B. 4306, F.B. 4004 and B. 219 were found to be very promising with regard to yield under Delhi condition. Varieties of yam, Queensland arrowroot and tapioca were also under observation. A variety of cow-pea from Philippines was found to be earlier in maturity by nearly a month than the commonly grown varieties.

Trials of introduced plants :—Some of the promising material like varieties of *Khesari* (*Lathyrus sativus*), Lehmann love grass, *Withamia coagulans* (vegetable rennet), Pejibaye palm (*Bactris utilis*), cinchona etc. were sent for trials to States.

SUGARCANE RESEARCH

PLANT COLLECTIONS

Scheme for spontaneum expedition :—As the success in sugarcane breeding has been mainly due to the wide range of collections of cane materials the programme of adding to the existing collections was reinforced by a scheme financed by the Indian Central Sugarcane Committee for the exploration and collection of *S. spontaneum* and related grasses. During the year the total number of 152 types, consisting of *S. spontaneum*, *Erianthus*, *Sorghum halepense* etc., were collected from a survey of important areas in South India (Madras, Mysore, Travancore and Coorg). The *spontaneums* added to the collections have a wide range of adaptability for different ecological conditions.

All the available collections are also maintained under subtropical conditions at Karnal. The maintenance of a live herbarium at Karnal is providing useful information for the selection of parents in the breeding programme for the production of economic canes suitable to north Indian conditions.

BREEDING

Test crosses :—The recognition of suitable parents for transmitting useful characters in the progeny is important for sugarcane breeding, specially in view of the complicated genetic constitution of cane materials. Experimental crosses have, therefore, to be made and progeny studied, for the selection of suitable parents for getting desired types of plants. Nine combinations of crosses were found to give economic types of seedlings. These crosses would be repeated in the next year on a large scale for making extensive selections.

Chewing types :—On the basis of the previous year's results two crosses were effected for obtaining soft rind seedlings for chewing purposes (C. 603 x E.K. 28; B. 6308 x Co. 290).

Commercial Canes :—From out of a total of 18,000 seedlings in the second ground nursery, 443 were selected for trial in the preliminary test plot. From the preliminary Test plot, 164 varieties were selected for trial in the Final Test Plot. In the last year's final test plot, 228 seedlings were under trial. Out of these, 56 were raised to the status of Co. canes, their numbers ranging serially from Co. 690 to Co. 745.

Tests for disease resistance :—Till now no serious attention has been paid so far at Coimbatore regarding breeding for disease resistance. This problem is now gaining importance as some of the Co. canes, like Co. 213, are found to be very susceptible to red rot. The selection of resistant parents

for red rot has therefore become one of the important items in the programme of breeding. With this object 59 Co. varieties, which have the parentage of Co. 213, were tested for disease resistance during the year with the co-operation of the Division of Mycology. Of the above, Co. 302 and Co. 634 showed the least infection. Smut tests will be continued on an extensive scale next year. A beginning has been made in the selection of parents resistant to smut.

CYTOGENETICAL STUDIES

Erianthus species :—Cytogenetical studies are in progress at the sugarcane station with a view to understand the genetical constitution of the various species of *Saccharum* and utilise the knowledge for breeding better types of canes. The types of *Erianthus* on cytological examination were found to fall in a polyploid series with $2n = 20, 30, 40$ and 60 chromosomes. A pentaploid ($2n = 50$) type was obtained by crossing *E. munja* ($2n = 60$) with *E. ciliaris* ($2n = 40$).

Interrelationship of different genera and Saccharum :—Of the seedlings obtained from the intergeneric cross *Narenga* x *Sclerostachya*, some were found to have exerted awns in their spikelets. The presence of awned IV glume in certain *Saccharum officinarum* types and also in *Erianthus* species indicate a close relationship of *Narenga*, *Sclerostachya*, *Erianthus* and *Saccharum*. A study of the floral characters of the selfed progeny of the variety *Ikra* provided additional evidence to the view that this variety is a natural hybrid between *Narenga* and *Sclerostachya*.

PHYSIOLOGICAL STUDIES

Control of flowering :—Investigations of the conditions governing the flowering of sugarcane are in progress with the object of bringing into breeding certain useful non-flowering canes as well as to delay or hasten flowering in parent canes for hybridization. By adjusting photo-period, irrigation and manurial treatments it was found possible to delay or hasten flowering in early and late varieties respectively.

Chemical composition of flowering and non-flowering varieties :—Comparative chemical analysis of flowering variety Co. 421 and a non-flowering variety Co. 468 has indicated that there was no marked difference except in soluble carbohydrate content and C|N ratio. C|N ratio was throughout at a higher level in Co. 468 than in Co. 421.

BOTANICAL STUDIES

Occurrence of starch in stems of Saccharum :—Studies on the occurrence and amount of starch in the stem of sugarcane varieties have given an indication that the presence or absence of starch is a definite specific character for certain species of *Saccharum*. Confirmatory studies are in progress. Preliminary studies have shown that early maturing varieties have smaller cells in their leaves than late varieties. The early maturing varieties have also accumulations of starch in the plastids when examined early in the morning. Studies are in the progress in a wider range of material for using this character in the initial stages of selection in sugarcane breeding.

CHEMICAL STUDIES

The chemical studies included the effect of soil conditions on growth and quality of cane varieties. A comparative study of the crop raised (Co. 312, 421 and 419) in garden and adjoining wet lands has confirmed the previous results in that the juice quality of the canes from wet lands in all cases was superior to the crop from garden land. Earlier maturity was obtained in wet lands.

SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

Effect of phosphatic manuring of berseem on soil fertility :—In an experiment started in 1946-47 to study the effect on soil fertility of phosphatic manuring of *berseem* in *berseem—guar* rotation, an increase in the uptake of phosphate by *berseem* has been noticed when doses of applied superphosphate are increased, but the high rate of uptake is checked when potash is used in combination with superphosphate. After three years the effect of these treatments on soil fertility will be assessed by growing wheat in *rabi* and maize in the succeeding *kharif*.

Wild leguminous plants for green manuring and fodder :—The scheme for nitrogen fixation originally contemplated an examination of wild leguminous plants. A study of the chemical composition of such plants and trees has been undertaken to investigate the possibility of utilizing the leaf for green manuring and fodder. Many of the species examined have been found to contain over 2 per cent nitrogen, which compares favourably with that present in the usual green manure and fodder crops like *berseem* (3 per cent. N) and sannhemp (2.3 per cent. N). Appreciable amounts of lime and phosphoric acid are also present. This indicates the possibility of utilizing these plants for green manuring and as fodder wherever available.

Conservation and utilisation of human urine as manure :—Human urine contains large amount of plant nutrients and attempts are being made to absorb it in suitable absorbing materials and utilising it as a manure. Various absorbents such as soil, saw dust, charcoal dust, coal ash, dry leaves and farm yard manure are being tried. The material after absorption of urine and drying in the sun has been found to compare favourably as a manure with other nitrogenous fertilizers.

Effect of different rotations and manurial treatments on the nutrient status of soils :—Effect of heavy doses of fertilizers with and without a legume in rotation on crop yields and soil fertility has been studied. In the wheat-maize rotation, where the fertilizers were applied to the wheat crop, the soil decreased in its N, K_2O , and CaO contents. With inclusion of a legume in the rotation, however, which was wheat—maize—peas—maize, the fertilizer being applied to *rabi* crops as before, the nutrients status of the soil practically remained unchanged.

Experiments in lysimeter blocks :—Raised plot (lysimeter) experiments with wheat are being continued for several years to examine the influence of fertilizers on the building up of soil fertility when legumes are either included in the rotation or excluded from it. *Berseem* and cowpea were grown for three years in *rabi* and *kharif* respectively, followed finally by wheat. Two types of rotations, one purely cereal and the other with inclusion of legumes, viz. wheat—marwa (*Eleusine corcana*)—wheat—marwa and *berseem*—cow

pea—wheat—cowpea were used. Preliminary results obtained so far show that soil fertility is better built up by following a legume rotation than by a purely cereal rotation.

A large number of plants have been tried for their suitability as indicators of mineral deficiency as exhibited by visual symptoms or response to crop yield by added fertilizer. In the year under report, two soils, one rich and the other poor in N and available P_2O_5 were used in pots, with maize in *kharif* and *berseem* in *rabi* as indicator plants. In conformity with previous years' results nitrogen deficiency in maize was indicated in pots receiving PK only, while the plant in pots receiving NK treatments indicated the usual phosphate deficiency, with *berseem*, 40 per cent. of the plants grown in the soil poor in N and available P_2O_5 showed reddening symptoms in the control, but this reduced to 2.5 per cent. and 0 per cent. with 200 and 250 lbs. P_2O_5 respectively. With the soil rich in N and available P_2O_5 , 14 per cent. showed these symptoms in the control. But P_2O_5 at 150 lbs. per acre reduced it to 10 per cent.

Manganese contents of Indian soils :—The manganese status of Indian soils has been studied by collecting a large number of soil samples from all over the country and analysing them for their contents of manganese in the form of water soluble, exchangeable, reducible, active i.e. the sum of water soluble, exchangeable and reducible, and total. Soils of per-humid zones are very low in active manganese, being 74.2 p.p.m. as compared to 320 of humid zones.

Work on deficiencies of gram :—Work on "top yellowing", "bronzing" and "yellowing and bronzing" diseases of gram has been continued. In conformity of results obtained in previous years, leaves of plants showing "top yellowing" were found to be associated with lower contents of manganese, while those showing "bronzing" with lower P_2O_5 contents, as compared to healthy ones. 1948-49 results, for example, show 45-50 p.p.m. Mn in leaves of gram showing symptoms of "top yellowing", the healthy ones containing about 100 p.p.m. Plants with symptoms of "bronzing" contained 0.45 per cent. P_2O_5 in their leaves, while the healthy ones contained 0.84 per cent. Boron content of the diseased leaves was lower (about 30 p.p.m.) than those of healthy ones (over 40 p.p.m.).

Deficiency diseases of citrus :—Systematic investigations on the mineral deficiencies in citrus have been taken up. In Coorg gummosis, stemborer, top-shoot borer and aphid and also mottle leaf symptoms and die-back have been traced to manganese and zinc deficiencies. This has been corroborated from responses to diagnostic injections and spray treatments with Mn and Zn.

Spectroanalytical techniques for the estimation of trace elements like Mn, Zn, Co, B, Mo and Cu are being developed.

Electrochemical properties of hydrogen clay colloids from typical Indian soils :—Electrochemical and related properties of hydrogen clays prepared from horizon samples of a black cotton soil profile from Indore are under investigation with a view to find their mineralogical composition and so to gain fuller information on the genesis and development of these soils. The nature of the potentiometric titration curves with bases, high base exchange capacity, variation of viscosity with increasing base saturation and thermal dehydration studies show that the dominant mineral contained in these clays belongs to the montmorillonite group. Presence of non exchangeable potassium to the extent to 1.8 per cent. K_2O , however, indicates the occurrence of about 20 per cent illite in these clays.

Soil Survey of Delhi and Karnal Farms :—In the initial layout of the Delhi farm area, drastic levelling involving earth removals and fill-ups resulted in a heterogeneity of the soil causing wide variation in yields in field experiments. A detailed soil survey of the area has, therefore, been taken up to examine the soils and prepare soil maps of the different blocks. The fluctuations of water table are also being studied. A similar detailed soil survey of Karnal farm area has also been undertaken.

Rann of Cutch :—A rapid reconnaissance soil survey of the Rann of Cutch was carried out in 1947, at the instance of the N. W. Railway (now B.B.C.I.R.) to assess the suitability of the area for reclamation and agricultural development. Chemical analysis of profiles collected from these areas show high salt content of the soils, chlorides and sulphates being present predominately. In some areas appreciable amounts of gypsum are present. Predominance of micaceous group of clay minerals in these soils is suggested judging from high non-exchangeable potash content (over 4 per cent. K_2O) in hydrogen clays and from the base exchange capacity of these clays which varies between 20 and 40 m.e. per 100 gm.

Narmada Valley :—At the request of the C.W.I.N.C. a soil survey of the Narmada valley project area has been carried out. The soil belongs to the black soil group and is clayey in texture. Detailed analyses of the samples are under way in order to judge the suitability of these areas examined for irrigation.

Insecticides :—Synthesis of some halo-and thiocyno derivatives of terpenes have been taken up. Preliminary screening tests with some of the compounds show that they are promising as insecticides against aphids. Isobornyl thiocyanacetate has been obtained in the laboratory in 90-95 per cent. yield.

Analysis of oils in seeds :—A semi-micro method for the estimation of oils in seeds has been successfully devised. The results obtained by this method agree very well with those obtained by Soxhlet extraction.

Residual effect of different forms of phosphates :—Experiments were carried out to examine the residual effect of superphosphate applied in two doses 60 lbs. and 120 lbs. P_2O_5 per acre, to pea. Three crops, viz., pea, maize and pea were taken, followed again by pea in 1948-49. Uniformly high yield upto over 80 per cent. increase over control was recorded in plots receiving 120 lbs. P_2O_5 per acre, suggesting that heavy manuring with phosphate may have a long-term effect even upto the fourth crop.

Utilization of different forms of phosphates for nitrogen fixation :—Experiments carried out with superphosphate, ground bone meal, Trichi nodules and Singhbhum phosphate showed that all of them increased nitrogen fixing power of pea, the amount in lbs. of N fixed per lb. of P_2O_5 being 0.93, 0.86, 0.35 and 0.25 respectively. Pea is thus capable of making use of indigenous insoluble phosphates though to a somewhat less extent as compared to superphosphate.

Nitrification :—Experiments on nitrification of different organic manures like oil cake, farm yard manure and composts under varying conditions of moisture and temperature in different soils which were started last year, were continued. The nitrogen in sannhemp seeds amounting to 6 per cent. has been found to nitrify as rapidly as mustard cake.

Chemical composition of Indian grasses :—A number of indigenous varieties of grasses grown by the Division of Agronomy were analysed for

crude and true proteins, either extract, N-free extract, crude fibre, ash, silica and insoluble residues, phosphoric acid, lime etc., in cuttings at intervals of one month. This system of cutting has been found to maintain a high level of protein (3.72—10.80 per cent.) and phosphoric acid contents (0.45—0.93 per cent. P_2O_5) in these grasses.

As cobalt and copper have often been linked with certain nutritional disorders in animals, micronutrients status of these grasses and fodders are also being investigated.

*Influence of manures and fertilizers on the nutritive value of cereal crops :—*Experiments have been undertaken to find the effect of manure and fertilizer treatments on the protein, minerals, vitamin B₁ and B₂, nicotinic acid and pantothenic acid contents of wheat. Wheat samples grown in the permanent manurial rotational series at Pusa (Bihar) have been examined for this purpose.

*Studies on the metabolism of soil organisms by soil perfusion technique :—*Soil perfusion technique has recently been developed for the study of the metabolism of micro-organisms in India soils, under different conditions. This technique ensures standardisation of soil conditions and facilitates homogeneous oxygenation and distribution of water in the experimental soil.

ENTOMOLOGY

*Studies on insect taxonomy :—*Among the immature stages of insects which cause serious damage to economic crops, caterpillars, of moths and butterflies come foremost. It is very difficult to identify the species in the larval stages. A study in this direction was made in the case of caterpillars of *Phisia* spp., a common pest of lucerne, berseem, gram etc., by the arrangement of groups of hairs present on their bodies. The results have been written up in a paper for publication.

Detailed studies of the sexes of Bruchid beetles, pests of pulses of India and Ceylon were carried out with a view to differentiating the various species correctly. A total of three genera including eleven species of Bruchids from the National Pusa Collection were studied and a paper has been completed for publication.

Control of insect pests by means of their natural enemies :

*Experiments on biological control :—*The results of field experiments to control the caterpillar borers of stem and root of sugarcane by field releases of the egg parasite (*Trichogramma*) in cultivators' fields and factory farms in different parts of India have been very encouraging. As a result of this, the sugar factories at Nellikuppam (Madras) and Walchandnagar (Bombay) have started mass breeding of this useful insect for treating large acres of sugarcane in their farms. *Trichogramma* parasites are being produced at a low cost of about Rs. 6/- for treating one acre of sugarcane in a season.

*Fundamental studies of insect parasitisms :—*Special investigations were carried out on some beneficial parasites used as agents of control, with a view to determine the merits of each parasite and also to develop suitable and efficient methods of mass-breeding them in the laboratory.

*Studies on Trichogramma :—*These studies on the egg parasite of sugarcane borers have shown that these parasites can be safely stored in a frigidaire at 10-12°C. for 15 days without affecting the life of the parasite. Similarly,

investigations on the effects of different kinds of sugars on the life-span and egg-lying capacity of this parasite have shown that the life of the parasite was increased to about 5-7 times in males and 7-9 times in females when fed with various sugars as compared to those that were starved; similarly the egg-laying capacity significantly increased when fed with different sugars.

Insect Ecology and Toxicology :—Intensive fundamental investigations in Insect Ecology and Toxicology yielded results which are of vital importance in planning insect control with a view to secure maximum success at minimum cost. It was shown that total *Effective Resistance* of insects to insecticidal chemicals can be resolved into *Surface Resistance* and *Internal Resistance*, and that contrary to earlier views the temperature co-efficient of DDT entry into insects' systems is positive irrespective of concentration; that the effect of particle size on the toxicity of DDT suspension sprays is governed by two factors viz. *contact factor* and *drain off factor* and that the temperature existing before the application of insecticides has a profound effect on the susceptibility of the insects.

MYCOLOGY

Indian Type Culture Collection :—The Indian Type Culture Collection of fungi which forms an important basis of mycological research has now reached the number, 750. This Collection maintained in the Division of Mycology and Plant Pathology became a Member of the International Federation of Culture Collections which is linked to the UNESCO and is collaborating with it in furthering its objects of promoting closer co-operation between the Culture Collections of the World.

Lentil wilt :—Wilt in lentil was shown to be caused by *Fusarium orthoceras*. Low soil moisture, good aeration and temperatures between 23°-31°C, were found to be favourable for the disease.

Oat leaf-spot :—In Leaf-spot of oats it has been observed that primary infection increases with fall in soil moisture. Two wild grasses *Phalaris minor* and *Avena fatua* were found to be collateral hosts.

Linseed rust :—Seventy varieties of linseed out of 125 varieties tested for their resistance to 4 physiologic races of rust proved to be resistant to the disease.

Sugarcane red-rot and smut :—Twelve varieties (including certain *saccharums*) of sugarcane out of 107 cane varieties tested reacted as resistant to the red-rot disease. Out of 96 parent cane varieties tested for their resistance to sugarcane smut, 53 showed less than 5 per cent infection and may be regarded as highly resistant, and 9 varieties out of 31 varieties newly released by the Sugarcane Breeding Station also appeared to be resistant to the disease.

Pigeon-pea wilt :—Low incidence of pigeon-pea wilt in unsterilized soils has been explained on the basis of the activity of the associated microflora, particularly two isolates of bacteria which belong to the *Bacillus subtilis* group. Relative colonisation of the straw by the soil fungi and bacteria during the growth of pigeon-pea plant showed considerable variation. It is likely that there is some correlation between abundance of some of the organisms and reduction in the incidence of pigeon-pea wilt disease. Inhibition of germination of spores of *fusarium udum*, the causal organism, and subsequent abnormal morphological changes in the germ tubes serve as an indicator of the antibiotic substance. Importance of manganese, magnesium and iron in the production of antibiotic substance has been shown.

Fungicides :—Tests conducted with different fungicides showed increased germination in maize with Ceresan and Agrosan GN by 10 and 9 per cent. respectively. In *jowar* and *bajra* an increase of about 15 per cent. was obtained with Agrosan—G.N. During the *rabi* season seed-treatment of oats with Ceresan gave 19.2 per cent. higher yield and there was no incidence of covered smut of oats in the crop raised from infected seed treated with Ceresan, Aagrano, Agrosan—GN, whereas in the untreated lot the diseased incidence was as high as 17 per cent. Seed treatment of barley with Ceresan gave a yield increase of 8.5 per cent.

Assessment of damage by fungi :—With a view to assess damage in the case of late blight of potato, a correlation has been established between the leaf-area affected and the yield. Ninetyfive to 100 per cent infection of the leaf-area brought about a reduction of 50 per cent. in yield whereas 25 per cent.—50 per cent. infection of leaf-area reduced yield by 21 per cent. The percentage reduction in yield of Agra-local wheat showing 75 per cent. of black rust infection was estimated to be 26.6, whereas in N.P. 4 with 50 per cent. infection a reduction of 20 per cent. was recorded.

Viruses :—Indications were obtained that the virulence of the tomato-leaf-curl virus is adversely affected after its passage through *Capsicum annuum*, *Solanum nigrum* and *Amarantus viridis*. Veinal necrosis in tomato was shown to be caused by a mixture of *Solanum viruses* 1 and 2. Also a new strain of bottlegourd mosaic virus was described. Virus-free nucleus material of *Darjeeling Red Round* and *Up-to-date* potato varieties was under multiplication with a view to produce a large quantity of seed stock for ultimate distribution to the growers.

AGRICULTURAL ENGINEERING

Tests and Trials of Tractors and Engines :—(a) With a view to determine the practical and economic possibility of low H.P. walking type tractors, tests and trials were continued on a 5 H.P. Gravely model 'L' walking tractor fitted with an air cooled Engine. The tests revealed that these types of tractors were unsuitable for Indian conditions.

(b) Experiments have been carried out with a view to determine the possibilities of utilising low H.P. tractors in lieu of bullocks, for the operation of country plough both from an economic and practical view point.

(c) Comparative operational costs and rates of performance of different makes of tractors both of the wheel type and track type, some operating on kerosene and some on Diesel fuel were collected and full data compiled.

A mobile power unit :—(d) A 5-7 H.P. diesel engine, now being extensively advertised and sold in this country, was installed on a 4-wheeled structural frame work which was entirely built of scrap material generally available in a workshop. This unit was easy for transport by a pair of bullocks in farm areas. Although it was used for operation of a small threshing machine, it can be of use for operating any stationary unit such as a pump or flour mill etc. Its working was satisfactory and economical for light stationary work.

Twin Country Plough :—The design of an entirely new two bottom country plough was evolved. Twin ploughs operating with local Delhi bottoms and Ambala bottoms have been constructed. This design was the outcome of an original research project recently carried out by this Division

to study the economic and practical possibilities of country plough operation by a low horse power tractors in lieu of bullocks. It was discovered that the draught of two country ploughs, suitably coupled together, fell far short of draught that required for a single plough and it was immediately decided upon to investigate the possibility of designing a double *desi* plough capable of being operated by a single average pair of bullocks. The new twin plough has been successfully used for first and subsequent ploughings with a pair of bullocks. Its output is almost double compared to that of a single plough and the handling of the plough is much easier. Demonstrations of this plough have been given locally.

Utilization of rotted material from town refuse dump :—As a part of the compost development scheme of the Grow-More-Food-Campaign, the rotary screen designed last year was the subject of further experiment and trial. The machine, as now finally designed, has been fitted with a $1\frac{1}{2}$ H.P. petrol engine and the following performance figures were recorded during trial carried out at the instance of the Compost Development Officer, Ministry of Agriculture.

Total material fed at the hopper in maunds	
per hour	120 to 150
Maunds of finished material sieved and delivered per hour	80 to 100
Total petrol consumption per hour in pints	1.00 to 1.50

Harvesting machinery :—(a) The design and construction of a simple mechanically operated reaper suitable for operation in small wheat and paddy fields was started.

(b) Construction of small hand operated reaping machines to replace the hand sickle is in hand. Three alternative models have been constructed and are awaiting tests.

(c) Experimental work on a small Indian threshing machine which produces a grain sample requiring subsequent winnowing was started in order that such machines, by simple modification, can be made to produce clean samples. One machine is now ready for trial.

(d) Tests were conducted on two small threshing machines received from Denmark. These are suitable for threshing small grains such as wheat, oats, barley, rice. While working of these machines was satisfactory, their structure was weak necessitating frequent stoppages for repairs. Their size is unique and capital cost is low. Necessary modifications are in progress.

(e) A self-propelled combine was tried out in harvesting wheat and oats at the Indian Agricultural Research Institute farm both as a stationary unit and also as a mobile field machine. Generally the machine, which is complicated in the extreme, is not in its present design suitable for operation under conditions in India as they exist today. Modifications to these combines to be of use in India have been suggested to the makers.

Fertilizer Placement Machine :—On conclusion of initial experiments and modification to a fertiliser placement machine, a series of field experiments on placement of fertiliser were carried out. In operation it was found that the placement of fertiliser in two bends was accurate *plus or minus* 1.5 lbs. per acre. Further modifications to determine the best placement for maximum crop yields under Indian conditions are in hand and further tests and trials are in progress.

GENERAL FEATURES OF THE REPORT FOR 1948-49.

The Library:—The Library of the Institute possesses about one hundred thousand volumes and receives every important journals dealing with agriculture and the sciences basic to it. It is considered to be the biggest agricultural library in India and one of the best in all-Asia. As one wing of the building is occupied by the library of the I.C.A.R. at present, there is insufficient space for the new books and periodicals that are being received.

The total number of publications received in the library during the year under report, both by way of exchange, donation and purchase, was 2,569. Fourteen new periodicals were added to the Library while seven were discontinued. The number of books issued on loan was 4,838 out of which 1,158 were sent out to scientific workers in the provinces and universities. The visitors who made use of the Reading Room totalled 7,684 and they consulted 81,028 books.

References supplied during the year to the Ministry of Agriculture, I.C.A.R., State Departments of Agriculture, Universities and individuals included the following:

- (i) Literature on : the Orobanch parasite; bamboo and its cultivation; the fungicide spergon; power alcohol; mushroom culture, sunflower; soybean; poultry; paddy; the sugar industry; cultivation of sugarcane, maize, wheat and barley; different breeds of cattle in India; the striga parasite; plant introduction; saline soil.
- (ii) Lists of books, *etc.*, popular books on agriculture, books and journals on agriculture and allied subjects, periodicals on agriculture with special reference to sugarcane, agriculture and dairy farming, gardening and agriculture in India, agriculture and fruit gardening, cultivation of crops and their improvement, Hindi books on agriculture. (iii) Information on soil fertility and the earth worm, cultivation of cloves in India.

Schemes :—The Schemes financed by the Indian Council of Agricultural Research for the introduction of Economic Plants, Improvement of the Maize crop in India, Breeding Wheat for the Hills and Breeding Potatoes for North India continued to function at the Institute. The last mentioned scheme, however, as already mentioned was transferred to the Central Potato Research Institute in May, 1949. Nitrogen Fixation Scheme. Scheme of Research on Minor or Trace Elements in Indian Soils and Plant Nutrition and Phosphate Monograph Scheme financed by the Indian Council of Agricultural Research were continued during the year. The Scheme on Palmyra Palm Gur financed by the Ministry of Agriculture was also continued.

The Seed Potato Certification Scheme financed by the Indian Council of Agricultural Research and the Scheme on Diseases of Sugarcane Research financed by the Indian Central Sugarcane Committee were in operation during the year.

The combined scheme financed by the Indian Central Sugarcane Committee for (i) research on the biological control of sugarcane borers at various centres and (ii) the biology and control of sugarcane pests by cultural, chemical and other methods at four centres, (1) Pusa (Bihar), (2) Banki (Orissa), (3) Nellikuppam and Coimbatore (Madras) and (4) Walchandnagar (Bombay) continued to be in progress. The pest part of the scheme was in progress in Bodon (Hyderabad Division) and Shahjahanpur (U.P.).

Advisory and survey work :—The Institute received a large number of requests for supply of information, technical advice, manuscripts of research papers for referring, writing of reviews of scientific books, identification of different kinds of biological material, analysis of samples, *etc.* Such technical assistance rendered by the various Divisions of the Institute during the year is summarized below:

The Air Head Quarters requested for advice regarding grassing of the shoulder strips of the runways at one of their airfields, lest grass should grow tall and tussocky and not keep a smooth surface for emergency landing and also for preventing fire risk from jet aircrafts. It was suggested that a suitable mixture of grasses and legumes should supplement the initial seeding with *dub* grass (*Cynodon dactylon*). Samples of *Phalaris minor* and strawberry clover seeds were supplied to the West Bengal Government. Samples of strawberry clover and subterranean clover seeds were also sent to the Assam Government. Pasture and hay grasses suitable for the Mathura area were recommended to the Dairy Demonstration Farm, Mathura. The luxuriant growth of *Setaria palmefolia* attracted much attention. The activities of the Division further included advice to individual farmers, land owners, dairymen, *etc.*, on crop rotation, fodder production for dairy herds, cultivation of new crops such as soybeans, rhodes grass, *etc.*, phosphate and nitrogenous manuring of various crops, management of soils and cultural practices.

The Division of Agricultural Engineering answered a number of enquiries from agriculturists all over India seeking advice on engineering aspects with a view to improve their present farm operations. These have pertained mostly to pumping plants for irrigation, and selection of tractors and other farm machinery to suit the individual needs of the agriculturists.

The Division of Botany received a large number of enquiries from different parts of India and abroad. These were duly dealt with and suitable replies sent to the respective parties. The enquiries that have been received mainly related to :

- (1) Exchange of seeds and plant specimens.
- (2) Methods of breeding, cultivation, and their techniques.
- (3) Identification of plants.

It has been observed that although India received numerous requests from overseas for plant materials, she has not been able to get the reciprocal benefit from these countries. Besides, unrestricted collection of horticultural bulbs and plants may lead to the risk of some species being completely wiped out from our country. This has been pointed out to the Government of India and it has been suggested that a central organisation like the proposed Bureau of Plant Introduction might be entrusted to deal with this subject as a part of their normal routine work. Other advisory work included : (4) Notes prepared for the Secretary, Indian Central Jute Committee, on *Hibiscus subdariffa* var. *altissima* as a possible substitute for jute, (5) Notes on Kudzu vine (*Pueraria hirsuta*) prepared and supplied to the Botanist in-charge of Soil Conservation and Research, Viswa Bharati, Sriniketan, West Bengal, (6) Information about the availability of seeds of *Carissa granatiflora* A.D.C. supplied to the U.S. Embassy, New Delhi, (7) Information about some species of grasses which stand water-logging given to the Agricultural Commissioner with the Government of India, (8) Information

given to the Executive Engineer, C.P.W.D., Dehra Dun regarding the use of sodium arsenite for control of weeds near the roads, (9) Information about the different varieties of plants evolved at this Institute sent to the Ministry of Agriculture, (10) Information supplied to the College of Agriculture, Davis, California, U.S.A. about cultivation of *Sesamum*, (11) Supply to the I.C.A.R. of information on *jagni* oilseeds, *Guizotia abyssinica* (niger), (12) Information on the technique of using colchicine for producing polyploids in plants, supplied to Mr. R. Chatterji, Nurseryman, Darbhanga, Bihar, (13) A note on the use of potato chips, eyes and sprouts and another on dormancy in potato tubers prepared for the Refrigeration Engineer, Ministry of Agriculture, (14) The U.K. Trade Commissioner, New Delhi was supplied with information on *Hibiscus sabdariffa* as a possible substitute for Jute, (15) The Assistant Agricultural Commissioner, New Delhi was given information regarding names of plant species collectively known as "Hemps", (16) Information given to Messrs. Ice and General Mills, Meerut City regarding the effect of storage in low temperature (40°F) on germinating capacity and disease resisting ability of wheat, (17) Seed samples received from time to time from the Directorate of Marketing and Inspection were identified, (18) A note on raising food crops like maize, sweet potatoes and potatoes in the field from which sugarcane has been harvested was prepared for the Ministry of Agriculture, (19) Information on *Lathyrus sphaericus* sent to the Director, Nutrition Research Laboratories, Coonoor, (20) Information on the cultivation of Lima bean, *Phaseolus lunatus*, supplied to the Director, Horticultural Research, New York, (21) The Marketing Adviser, New Delhi was supplied information on the cultivation of *tapioca* in India, (22) Information given to the Directorate of Economics and Statistics, New Delhi on the N.P. wheats suitable for Delhi Province, (23) Information on the utilization of sea weeds as food given to Sri Joshi of the Industrial Machinery Supply Co. Bombay, (24) Information on the methods of cultivation and extraction of fibres of flax and hemp supplied to Nepa Mills, Chandani, C.P., (25) The I.C.A.R. was furnished with information about the performance of bird's food trefoil (*Lotus corniculatus*) in the Division of Botany.

The Division of Soil Science and Agricultural Chemistry supplied information to Mr. K. H. Advani, Assistant Agricultural Commissioner, I.C.A.R., regarding the use of wool waste as manure, its scope and work done in India. A report was sent on the analysis of soils of the Andaman and Nicobar Islands, received through the Ministry of Agriculture. Cultures of root nodule organisms of *Senji*, *Shaftal* and lucerne were supplied to the Superintendent, Central Cattle Breeding Farms, Jubbulpore, C.P. A culture of the berseem root nodule organism was supplied to Jamadar Mukund Singh of Meerut. A culture of butanol producing organisms was supplied to Dr. B. Guha of the Calcutta University. Soy-bean culture was supplied to the Government Agricultural Chemist, Coimbatore. Mr. B. R. Rai Singhani, Soil Survey Officer, Cashewnut Enquiry Committee, I.C.A.R., was supplied with literature and information on the soils of Bombay and Madras Presidencies. Information was supplied to Mr. M. M. Ismail, North Arcot, on the production of white oil and vanaspathi. Replies were sent to the questionnaire of the Patent Enquiry Committee set up by the Government of India. Soil Surveys were undertaken in the Narmada Valley in connection with an irrigation project at the request of Central Waterways Irrigation and Navigation Commission. The Soil Survey at Jubbulpur undertaken in 1947-48 at the request of the Animal Husbandry Commissioner, I.C.A.R., in connection with the establishment of a Cattle Breeding Station was continued.

In the Division of Mycology and Plant Pathology identification of pathogenic and taxonomic specimens was made for research workers of different provinces and universities. Information regarding literature and distribution of fungi was supplied as and when asked for. Notes were written and supplied in connection with scientific enquiries. Over 600 samples of seeds and plants were examined, treated and necessary certificates of health were issued. Diseased specimens were supplied on request to the Mycologists of West Bengal and Madras. Coloured plates of plant diseases were supplied to the Mycologist of Assam. Diseased material received from Cochin, West Bengal, U.P., Assam and Jaipur was examined and reported upon. Information on the occurrence of certain fungi and mycological literature was supplied to the Departments of Agriculture, C.P., East Punjab, U.P., West Bengal and the United Planters' Association, Nilgiris. In addition, cultures and diseased material were identified for different universities.

The Division of Entomology received 42 parcels for identification, from different provinces. These parcels contained 319 species of insects including 99 species of Coleoptera, 53 of Hymenoptera, 53 of Lepidoptera, 9 of Orthoptera, 42 of Diptera, 57 of Rhynchota, 2 of Neuroptera, 1 of Dermaptera, 1 of termites and 2 of mites.

The organisations and persons for whom identification was done included the following :

Plant Protection Adviser to the Government of India; Central Potato Research Institute; Central College of Agriculture, Delhi; Joshi's Hospital, Delhi; Department of Zoology, Allahabad University; Indian Veterinary Research Institute; Animal Husbandry Officer, Himachal Pradesh; Lac Research Institute, Ranchi; Entomologist, C.P.; Entomologist, Gwalior; Turmeric Research Assistant, Ganjam (Orissa); Entomologist, East Punjab; Haffkin Institute, Bombay; Entomologist, Coimbatore and Bapatla.

The following correspondents were supplied with information on the subjects mentioned against each.

- (1) A note on the control measures against pests of brinjal was forwarded to the Managing Agent, Manibar Stone & Lime Co., Ltd., Calcutta.
- (3) Information regarding control measures against aphids was supplied to Sri C. L. Patel, Honorary Secretary, Federation of Rural Peoples' Organisation, New Delhi.
- (3) Information regarding the distribution, host plants and literature regarding the species *Alcides porrectirostris* Marshall was supplied to the Director, Plant Protection, Government of Pakistan, Karachi.
- (4) Suggestions on the various publications and recent literature on sericulture were sent to the Superintendent, Sericulture, U.P., Dehra Dun.
- (5) Information regarding the eggs of *Phasmidae* was supplied to M. L-abbe Favorella, Faculty Librades Sciences, Lille (Nord), France.

The Principal of the Agricultural College, Amritsar, was supplied with 13 species of Hymenoptera, 15 of Rhynchota, 12 of Diptera and 1 of Isoptera. The Entomologist, Central College of Agriculture Anand Parbat, Delhi was supplied with 54 species of Lepidoptera, Diptera, Hymenoptera, Coleoptera, Neuroptera, Rhynchota, Isoptera and Orthoptera.

A culture of 2,88,000 *Coreyra* eggs was sent to the Entomologist, Walchandnagar and another culture of 18,000 *Coreyra* eggs was sent to Dr. Tashkir Ahmed, Plant Protection Adviser to the Government of Pakistan. About 84,000 *Trichogramma* parasites were sent to the Sugarcane Entomologist, Cuttack ; about 12,000 parasites to the Assistant Entomologist, Gurdaspur ; about 18,000 parasites to the Plant Protection Adviser, Karachi (Pakistan) and about 1,02,000 parasites to the Entomologist to the Government of C.P., Nagpur.

The following coloured plates of insects were supplied :

- (1) 8 coloured plates to the Ministry of Broadcasting, Government of India.
- (2) 150 coloured plates to the Pakistan Government.
- (3) 11 coloured plates to the Plant Breeding Officer, Karjat, District Kolaba, Bombay.
- (4) 52 coloured plates to the Director of Agriculture, United States of Rajasthan, Udaipur.
- (5) 50 coloured plates to the M.E.S. Higher Secondary School, New Delhi.

Collections and herbaria :

Crop Plants.—The Institute maintains collections of different species of varieties of crop plants such as wheat, barley, potatoes, linseed, chillies, pigeon-pea, etc. In wheat alone, the number of cultures are about fourteen hundred. During the year under review, the living collections of the various crop plants were perpetuated. Recently the Food and Agriculture Organization of the United Nations has undertaken to establish a world cataloguing service of genetic stocks for plant breeders and geneticists in order to give them assistance with respect of available plant breeding material and the names, locations and type of work being done by other breeders. As a first step the F.A.O. has taken up the preparation of a world catalogue of wheat stocks and they have invited the cooperation of our country in the project. The Government of India in accepting the proposal have nominated the Director of this Institute to be in charge of the work to be done in India. Accordingly, arrangements were initiated by the Institute to describe, according to the standard schedule laid down, the genetic material of wheat available in India.

Fungi and microorganisms.—The collection of fungi maintained at the Institute includes more than 750 cultures. During the year under review, the Institute in view of the Indian Type Culture Collection of Fungi maintained in the Division of Mycology and Plant Pathology became a member of the International Federation of Culture Collections which is linked to the UNESCO through the International Association of Microbiologists and the International Union of Biological Sciences. The Institute is collaborating with the International Federation in furthering its objects of promoting closer cooperation between the different culture collections of the world, as well as the preparation of a world catalogue of strains. This Institute is also represented on the Indian National Committee on Type Cultures of Micro-organisms and, through the latter body, is also a collaborating member of the "Commonwealth Culture Collections of Micro-organisms." A number of cultures were supplied by the Institute to various research workers, industrial concerns and Departments of Agriculture in India.

Insects:—The National Pusa Collection of insect includes a large number of specimens. Twenty-six species of insects, not previously represented in the collection, were added during the year under report. Many insect specimens were sent out to experts in India for identification and study, besides a consignment of fruit flies sent to the University of Hawaii and insects of various orders supplied to the Natural History Museum, London. Progress was made in the catalogueing of a number of orders including the Coleoptera, Diptera, Rhynchota, Hymenoptera, Orthoptera and Neuroptera.

Herbaria:—In the Division of Mycology the Herbarium contains 18,750 specimens and 12 exsiccata sets. Two hundred and eight specimens from the herbarium were supplied to various research workers (of which 91 were supplied to the Plant Protection Adviser to the Government of India) and teaching institutions. A small herbarium at present mainly limited to the plants of Delhi province has also been recently established in the Division of Botany.

Soil monoliths:—A Central Committee of Soil Science under the Ministry of Agriculture was constituted for laying down an uniform procedure for soil survey in the different States and collection of typical soil monoliths from all over India to be preserved at the Institute.

Plant introduction and trials of promising varieties:—Introduction of new economic plants or improved varieties of existing crop plants from one country to another and also the study and utilisation of their wild relatives which sometimes possess useful characters, constitute important methods of modern plant breeding. Realising the importance of this work, a beginning has been made in this direction by the establishment of a small nucleus organisation financed by the I.C.A.R. A large collection of indigenous and exotic plant materials has already been made and is being studied in the Division of Botany for assessing its value for direct utilisation or through hybridization, etc. The following is a statement of seeds imported from foreign countries during 1948-49.

Name of the crop	No. of varieties obtained	Countries from where the samples were obtained.
Cereals	116	U.S.A., Australia, Brazil, Turkey and Sweden.
Pulses	22	U.S.A., Brazil, Sweden and Cyprus, Philippines.
Oilseeds	31	U.S.A., Turkey, Cyprus, Sweden, Netherlands, Australia and South Africa.
Fibres	6	Brazil, New Zealand and Sweden.
Narcotics	7	U.S.A., Australia and Turkey.
Vegetables	44	U.S.A., Australia, Canada, Brazil, Sweden, Ceylon, Burma & W. Africa.
Tuber crops	24	U.S.A., Sweden and South Africa.
Grasses	52	U.S.A., Australia, Brazil & Uruguay.
Legumes	65	U.S.A., Brazil, Newzealand, Cyprus, Australia, Sweden and Uruguay.
Medicinal Plants	14	U.S.A., England and Australia.
Wild relatives of brinjal, tomato, linseed, oats, barley, okra, sunhemp, etc.	15	England and South America.

Several kinds of seeds and planting materials were supplied to provincial departments of Agriculture, scientific workers in the universities, and research institutions and other individuals. In this connection mention may be made of sweet potatoes, various kinds of beans, groundnut, lupines, *khesari*, psyllium, datura, rye, wild species related to wheat, tomato, brinjal and okra and a new palm from Costa Rica, *viz.*, pajibaye palm.

Improved varieties of pulses, oilseeds, cereals, *etc.*, were supplied to foreign countries like the U.S.A., Sweden, Cyprus, Bulgaria, the Sudan and Transjordan, in exchange of material received from these countries.

New strains of rust-tolerant wheats, high yielding potatoes and sugarcane and rust-immune linseed evolved at the Institute were under trial in the provinces and states and the results on the whole were encouraging. The recently evolved N.P. strains of wheat just referred to were under trial at 26 stations representing the important wheat-growing tracts of India. Some of these have shown considerable promise. Promising hybrids of potato were tried at a number of hill stations in the provinces and some hybrids have now reached a multiplication stage in Bengal and U.P. As a result of work at Delhi on the selection of hybrids suitable for the plains in India, a few hybrids were sent for trial at six places in the provinces and the results were again encouraging. Fifty-six new varieties of sugarcane were sent out for trials in the States.

The study of tuber crops, which form an important subsidiary food, received close attention. An extensive collection of sweet potatoes, both exotic and indigenous, was under observation and a few promising varieties possessing early maturity and high yield have been selected for large-scale trials. The possibility of tapioca cultivation in parts of Northern India was being looked into. Varieties of yam and Queensland arrowroot were under observation to find out their suitability under local conditions. The extensive collection of tuberiferous species of *Solanum* including hybrids and commercial varieties was studied at Simla for assessing its breeding value and suitability for direct cultivation.

A number of well known exotic grasses and legumes was studied with regard to their growth and seeding capacity; the more promising ones were selected for further trials. Further information about these will be found in the report of the Agronomy Division. Arrangements were in progress to conduct yield trials in the provinces and states with the material of double crosses of maize received through the courtesy of Dr. P. S. Hudson of the F.A.O. A number of new plant materials were sent to different parts of India for trials.

Supply of pedigree seeds and stocks to Provinces and States :—The demand for N.P. seeds and particularly for N.P. wheats was as heavy as in past. N.P. 52 was in great demand from Bihar, Bengal and C.P. and the supply fell far short of the demand. The Botanical Division received 141 seed indents of which 66 were dealt with by the Division, 59 were transferred to the Botanical Sub-station, Pusa and 16 to the Agronomy Division. Thirty

of these indents were from cultivators. A statement showing the quantities of pure N.P. seeds supplied as foundation stocks is given below :

Crop	Seed supplied		Total
	Division Botany	Botanical Sub-station, Pusa	
Wheat	2192 lb.	9164 lb.	11356 lbs.
Barley	168	3035	3203
Oats	194	2853	3047
Gram	852	656	1508
Peas	485	706	1192
Rahar	..	58	58
Mung	..	43	43
Lentil	..	29	29
Urid	41	103	144
Linseed	29	29	29
Hibiscus	..	43	43
Tobacco	..	8	8
Paddy	..	604	604

The seeds supplied by the Division of Agronomy through the Rural Development Scheme, Delhi Province, consisted of 380 mds. of wheat, 25 mds. of maize, and 230 mds. of sugarcane. A demand for 1,194 mds. of seed cane from the Land Reclamation Organisation of East Punjab was met from the Karnal farm. Seed cane distributed to local cultivators aggregated 1,834 mds., the variety recommended being Co. 312. About 106 mds. of paddy seeds of different N.P.* varieties were supplied to displaced cultivators through the agency of district authorities, Karnal. Ten maunds of peas N.P. 29 were delivered to the Department of Agriculture, Jaipur. In view of the heavy demands for N.P. wheats 52, 80-5, 12 and 165, these varieties were multiplied for distribution to provinces and states as well for nucleus seed stocks of new partially rust-resistant strains.

The following quantities of seeds of improved varieties of crops were distributed by the Karnal Substation : 335.9 mds. of wheat, 9.6 mds. of peas, 1.0 md. of gram, 1194.2 mds. of sugarcane, 0.1 md. of cotton, 106.6 mds. of paddy, 0.5 md. of *moong*, 0.5 md. of *moth* and 0.25 md. of *anjan* grass.

The Agronomy Division supplied pedigree cattle from Sahiwal and Tharparkar herds to various indentors. The animals supplied from the Sahiwal breed were : 2 bulls to the Commissioner of Agriculture, PEPSU, 40 bulls to the Animal Husbandry Department, U.P., 2 bulls to the Government Livestock Farm, Hissar, 1 bull to the Director of Agriculture, Bombay, 8 bulls and 15 cows to the Assam Government, 1 cow to the Animal Husbandry Officer, Himachal Pradesh, 16 cows to the Director of Agriculture, Jaipur and 3 cows to the Director, Indian Dairy Research Institute, Bangalore. From the Tharparkar herd, 16 young bulls were supplied to the Director of Agriculture, Jaipur, 1 young bull to the Animal Husbandry Officer, Himachal Pradesh, 7 young bulls and 8 cows to the Director of Agriculture and Livestock, Assam and 2 cows to the Director, Indian Dairy Research Institute, Bangalore.

*N.P.=New Pussa. This prefix is applied to strains of crops plants evolved at the Institute.

Collaborative Research with the Provinces and States :—To determine the suitability of the newly-evolved varieties of various crop plants for the varying agricultural conditions prevailing in the country trials have been in progress in collaboration with the Provincial and State Departments of Agriculture. Yield trials were arranged with 12 varieties of wheat at 26 places; also nine rust-resistant hybrids evolved at Simla were grown at nine places. Other trials were of 12 potato hybrids, 35 rust resistant linseed hybrids and seven tomato selections. Some of the varieties have been favourably reported upon by the Provincial Departments.

When the quantity of seed of plants imported under the Plant Introduction Scheme is sufficient for the purpose, it is supplied to the provinces for direct trials ; in other cases attempts are made to multiply the seed and then take up the trials. The possibilities of introducing new plants from one province to another are also being examined. Arrangements have been made for the trial in the provinces and states of indigenous as well as American, Chinese and South African varieties of sweet potato, varieties of tapioca from Travancore, an American variety of groundnut, pejibaye plum (a useful source of food) from Costa Rica. Trials have also been in progress with the well-known soil conservation plants, *viz.*, love grasses (weeping love grass and Lehman love grass), Tropical Kudzu Lespedeza and other grasses and legumes. A Scheme of Trials with Nitrogenous and Phosphatic Fertilisers was sent to the Ministry of Agriculture for circulation to different States. The following States so far have agreed to conduct the trials:

Madras, Assam, Bihar, Punjab (I.).

Post Graduate Training :—Out of 139 applications forwarded by the authorities concerned in the States, 60 students were interviewed by the Institute Council and admitted. The number 139 does not, however, represent the full demand as many States have Selection Committees of their own which do a preliminary selection. Thus, for instance, in one State 94 candidates offered for admission to the Indian Agricultural Research Institute courses, 67 were called for interview and only 25 were recommended by the State Selection Committee.

Agronomy :—Eleven students completed their post-graduate training in the Agronomy Division and were awarded the diploma of the Institute. Twenty students were newly admitted for training; of these, four opted for training in Sugarcane Agronomy. Two Research Fellows were working in the Division upto the 14th of November, 1948. The first year students attended classes at the Karnal Substation for a month.

Theory and practical classes in Agricultural Engineering were held for the first year students of the Agronomy Division.

Botany :—Six students completed the post-graduate training and were awarded the diploma of the Institute. Nine students were promoted to the second year and after undergoing the prescribed course of lectures, practicals and field work, were allotted research problems. In the first year 16 students were admitted but two of them subsequently discontinued. Two honorary Researchers worked during the year under report. One of them working in the Physiology Section discontinued after six months while the other who worked in the Cytogenetics Section left after completing his work for the Ph.D degree of the Madras University.

Two Research Fellows were engaged in the problems on Plant Breeding and Genetics.

Chemistry :—Four students completed the training and were awarded the diploma. Six students entered the second year of their training and nine were freshly admitted. In addition one student received special training in the Soil Microbiology Section and two students were trained in the Chemical Analysis of Soils.

One Research Fellow worked on Clay Minerals, another on nutritional value of wheat, the third on the standardisation of microbiological method for estimation of vitamin B.

Mycology :—Three students received the diploma, Seventeen students, 9 in the first year and 8 in the second year, were under training. One short-course student was given training in the study of soil fungi. In addition to the practical and theoretical training imparted to the students of the Division a course of lectures was given to the students of other Divisions. Two Research Fellows appointed under a scheme financed by the I.C.A.R. carried out research work under the direction of the members of the staff.

Entomology :—Five students successfully completed their training and were awarded the diploma. Six students and one honorary researcher were admitted during the year and another continued to work till September, 1948.

Facilities were provided to a scholar of the Lucknow University for studying the toxic properties of three dozen compounds.

Conferences attended by the members of the staff :—A number of meetings and conferences were attended by the Director. These included the First Commonwealth Conference on Tropical and Sub-tropical Soils held in Harpenden, England; Reviewing Committee of the Indian Institute of Science, Bangalore; Committee on Soil Survey of the Central Board of Irrigation; Board of Agriculture, West Bengal; the Advisory Committee for Coordinating Scientific Work in India; Soil Survey Organisation Committee; Governing Body and the Advisory Body of the I.C.A.R., All India Council for Technical Education; Indian Science Congress. The Director also served on the Homoeopathy Enquiry Committee as its Chairman.

Agronomy Division :—Dr. T. J. Mirchandani accompanied the Director to attend the First Commonwealth Conference on Tropical and Sub-tropical Soil held at Harpenden.

Botany Division :—Dr. B. P. Pal, Dr. N. Parthasarathy and Mr. H. B. Singh attended the Indian Science Congress held at Allahabad during the first week of January, 1949. They also attended the annual meeting of the Indian Society of Genetics and Plant Breeding held at Allahabad at the same time at which Dr. Pal as the President took the Chair. Dr. B. P. Pal, Dr. N. Parthasarathy and Dr. P. N. Bhaduri took part in the symposium arranged at Bangalore by the National Institute of Science, in the first week of May, 1949 on "The present position of research in Cytology, Genetics and Plant Breeding in India". Dr. B. P. Pal acted as Chairman of the Botany Committee of the I.C.A.R. Dr. Pal also visited Australia for six weeks as a member of the Indian Scientific Delegation.

Chemistry Division :—Some of the members of the Division of Soil Science and Agricultural Chemistry attended the Indian Science Congress at Allahabad, the Defence Science Congress held at Delhi University, the meeting of the Animal Husbandry Wing of the Board of Agriculture in India and a meeting of the Committee on the irrigation of black soils held at Poona.

Entomology Division :—Dr. E. S. Narayanan and Sri T. V. Venkatraman attended the *Ad Hoc* Sugarcane Entomological Committee meeting held in October 1948. Dr. Mukerji and Dr. S. Pradhan attended the Entomological Committee meeting of the I.C.A.R. held in the same month. Dr. E. S. Narayanan and Dr. S. Pradhan attended the Inter Departmental Insecticidal Committee meeting held in November, 1948.

Dr. E. S. Narayanan and Dr. S. Pradhan and Sri C. K. Samuel attended the Indian Science Congress held in Allahabad in January, 1949. They also attended the Annual Meeting of the Entomological Society of India held at Allahabad during the session of the Indian Science Congress. Both Dr. E. S. Narayanan and Dr. S. Pradhan were elected as Vice-President and General Secretary of the Entomological Society of India respectively.

Mycology Division :—Dr. R. S. Vasudeva presided over the Agricultural Section of the Indian Science Congress held at Allahabad and delivered his presidential address on "Soil-borne plant diseases and their control". He also attended meetings of Rust Control Committee, Inter-Departmental Committee on Insecticides and Fungicides, Agricultural Research Sub-Committee of the Indian Central Sugarcane Committee, Botany Committee of the I.C.A.R., Oilseeds Committee and an *ad hoc* Committee to consider Plant Virus Schemes.

Agricultural Scientists' Conference :—At the instance of the H.M. for Food and Agriculture, a Conference of Agricultural Scientists was held at the Institute from the 6th to the 9th April, 1949 to make recommendations for rendering the country self-sufficient in food by 1951. The Conference, which was presided over by the Director, was inaugurated by the Minister for Food and Agriculture, the Hon'ble Sri Jairamdas Daulatram. Agricultural Scientists from all over the country attended the Conference and took part in the proceedings. Members from the different Divisions of the Institute also attended the meetings and presented papers.

Visitors' Day :—Sunday, March 20th, 1949 was Visitors' Day at the Institute devoted to demonstrate to the public the outstanding results achieved in the various Divisions. The Prime Minister, the Hon'ble Pandit Jawaharlal Nehru paid a brief visit to the Institute in the forenoon and addressed the students for a few minutes. In the afternoon the Hon'ble Minister for Food and Agriculture, many members of the Constituent Assembly and the public, including a batch of village headmen, gathered at the Institute. The Hon'ble Minister addressed the gathering welcoming the visitors and introducing to them the Institute and its activities. The visitors spent the whole afternoon at the Institute going round the various Divisions. They showed keen interest in the different kinds of exhibits and demonstrations held at the Institute.

Visitors :—During the year under review many distinguished persons visited the Institute. Among them were: Hon'ble Pandit Jawaharlal Nehru, Prime Minister; Hon'ble Sri Jairamdas Daulatram, Minister for Food and Agriculture; Mr. D. P. Fretter, Director of Extension Service, University of Texas, U.S.A.; The Chancellor of the Burmese Embassy, New Delhi; Mr. Thakin Ba Ha, Joint Secretary, All Burma Peasants' Organisation; Sri Kamta Prasad, Agriculture and Forest Minister, Bhopal State; Mr. Zahoor Hasmi, Minister of Health, Bhopal State; Sri Nanabhai Bhatt, Minister for Agriculture, United States of Saurashtra; Mr. Shankar Prasad, Chief Commissioner, Delhi; Mr. M. S. Randhawa, Deputy Commissioner, Delhi; Sri M. P. Patil, Minister for Agriculture and Forestry, Bombay; Sri Alfred C. Egerton, Royal Society, London; Dr. Ben Lockspeiser, Ministry of Supply, LICAR

London; Dr. S. S. Bhatnagar, Department of Scientific and Industrial Research, Delhi; U. Thein, Chief Agricultural Officer, Shan States; Mr. Peng Cheng Hsu, FAO, Nutrition Division, Washington, D.C.; Mr. W. R. Purnell, UNESCO House, Paris; Dr. A. Wolsky, UNESCO Science Cooperation Office, Delhi; Mr. A. Yuschak, Soviet Embassy, Delhi; Nine members of the Soviet Delegation; Sri B. Pattabhi Sitaramayya, Congress President; Mr. K. L. Punjabi, Secretary, Ministry of Agriculture; Dr. G. V. Jacks, Commonwealth Bureau of Soil Science, England; Charge d'affaires for Siam in India; Members of the Economy Enquiry Committee; Dr. J. Hundum, University of Aarhus, Denmark; Dr. S. Chapman of Queen's College, Oxford; Thakur Kushal Singhji, Minister for Public Works, Jaipur; Mr. N. E. Dodd, Director General, FAO; Mr. R. V. Phillips, Director of the FAO; Mr. R. L. Sethi, Agricultural Commissioner, I.C.A.R., Prof. Krishnan, National Physical Laboratory, Delhi; Mr. M. S. Panja, Minister for Agriculture, West Bengal; Dr. W. J. Ellis, UNESCO Far East Field Science Office; Mr. H. C. Yin, UNESCO South Asia Science Office; Rani Madhavi of Jashan Maharaj Kumar Karauli of Karauli State; Maj. Gen. M. S. Himatsinghji; Hon'ble T. K. Narayan Rao, Prime Minister, Travancore; Attorney General of Travancore; President of the Parliamentary Board, Travancore; Mr. C. I. Abraham, Finance Secretary, Travancore State; Mr. N. T. Mone, Joint Secretary, Agriculture Ministry; Mr. W. I. Ladejinsky, U.S. Department of Agriculture, Washington, D.C.; Sir Boyd Orr; Dr. P. S. Hudson, FAO.; Mr. P. K. Nambiar and 33 other I.A.S. Officers; Swami Bichitrananda Das, Advocate General, Orissa; Mr. W. H. Cummings, FAO Regional Representative, Bangkok. Several members of the Constituent Assembly also visited the Institute on various occasions.

REPORT OF THE DIVISION OF AGRONOMY.

Research.

The work is conducted under the following main heads ; through experiments at I.A.R.I. Farm at Delhi :—

- (i) Manurial experiments with nitrogen, phosphorus, potash, (organic and inorganic) and their combination and micronutrients.
- (ii) Cultural and cultural cum manurial experiments.
- (iii) Rotational, mixed farming and mixed cropping experiments.
- (iv) Varietal and varietal cum manurial experiments.
- (v) Agrostology—Collection of grasses and legumes, experiments on seed mixtures, ley farming etc.

Season.

The weather conditions were normal for the kharif crops. During July, August and September the rainfall was adequate (20.27") and well distributed. Relative humidity was high and mean maximum and mean minimum temperatures quite favourable for growth of kharif crops.

TABLE I.

Month	Mean Temp.		Relative humidity % (7 A.M.)	Rainfall inches	No. of rainy days.
	Max. °F	Min. °F			
July, 1948	96.3	80.9	81.1	7.10	15
Aug., 1948	91.4	81.0	95.0	9.05	21
Sept., 1948	91.2	75.3	86.3	4.12	7
Oct., 1948	91.1	67.7	81.2	0.51	2
Nov., 1948	81.0	49.9	79.7	0.00	0
Dec., 1948	72.9	44.5	83.1	0.01	1
Jan., 1949	72.2	46.0	84.6	0.07	2
Feb., 1949	74.0	47.0	84.3	0.64	4
March, 1949	84.4	55.5	71.5	0.24	2
April, 1949	99.7	68.0	43.6	0.00	0
May, 1949	104.0	79.7	46.1	0.48	3
June, 1949	104.8	82.7	43.0	0.12	1

Mean Temp.

Rabi :—Sowings had to be done after irrigating the fields in early October. Dry season prevailed right upto end of January. A few showers were received in February and March but April ran absolutely dry, which provided excellent conditions for harvesting. Temperatures showed a steady rise in spring months, and were very favourable for ripening of cereals. Threshing continued without a set back, as dry weather conditions in May favoured quick threshing of *rabi* crops.

Research Projects.

Effect of N, P, K and Ca in different levels and various combinations on wheat.—The experiment started in 1942-43. Due to high dosage of nitrogen the crops had been lodging year after year and no particular responses were shown except in 1947-48 when increasing doses of nitrogen resulted in higher yield of grain. In the year under report the crop again lodged disproportionately in the various plots. Therefore, extent of lodging was determined in each of the plots by mapping the area separately and determining the loss in grain yield of individual plots by lodging. It resulted in 63 per cent. fall in grain yield and 36 per cent. in straw outturn. Thus for every lb. of nitrogen applied there occurred a reduction of about 4.5 lbs. in grain yield.

TABLE II.
(Corrected yields).

Ammonium sulphate per acre					Mean yld. Mds.	Triple- superphos- phate per acre lbs.	Mean yld. Mds.	Potassium sulphate per acre lbs.	Mean yield in mds.
0 lbs.	..	..	..	..	32.9	0	34.4	0	35.3
100 lbs.	..	..	..	..	35.6	200	36.6	210	34.9
200 lbs.	..	..	..	..	38.0	400	35.6	420	36.0
C.D. @ 5 %	..	..	..	..	3.09	not significant		not significant	
C.D. @ 1%	..	..	..	..	4.08				

Grain yields, corrected for the adverse effect of lodging, indicated significant differences amongst the various levels of nitrogenous manuring. Response to manuring with phosphate or potash is not evident. The mean response, upto 100 and 200 lbs. ammonium sulphate dressings, per md. of the fertilizer applied worked out to 2.21 & 1.08 mds. of grain per acre respectively.

Relative value of nitrogen in organic manures and inorganic fertilizers.—The results of the experiment tabulated below indicated that grain yield response to green manuring the land with sannhemp was the best :—

TABLE III.

Treatment	Ave. yield of wheat in mds/acre
	1948-49
A. Sannhemp—Green manure 	24.3
B. Cowpeas—Green manure 	22.7
C. Rape cake @ 40 lbs. N.P.A. 	22.7
D. Castor cake @ 40 lbs. N.P.A. 	20.2
E. F. Y. M. @ 40 lbs. N.P.A. 	18.7
F. Compost @ 40 lbs. N.P.A. 	23.1
G. Amm. sulph. @ 40 lbs. N.P.A. 	23.2
H. No manure 	20.9
Critical difference @ 5% 	2.76

The results for last four years for that experiment has been in progress, have not shown constant results. The experiment will be run for 1949-50 and results analysed serially over the whole field.

Building up soil fertility through organic manures and inorganic fertilizers with and without legumes in rotation :—

The experiment started in 1946-47 with the following rotations :—

1. Wheat—Maize—Wheat—Maize.
2. Wheat—Maize—Peas—Maize.

The manuring was done to rabi crops only. The first cycle of this experiment completed in 1947-48 and a new cycle was started in 1948-49 under report. The results are given below :—

TABLE IV.

Yield of grains in Mds. per acre.

Wheat Pb. 228.

Treatment/acre	(1)	(2)
	Rotation with- out legume	Rotation with legume
A. No. manure	8.6	16.7
B. Am. sulph. 60 lbs. N, super 100 lbs. P_2O_5 Pot, sulph 100 lbs. K_2O	20.1	22.8
C.F.Y.M. 60 lbs. N, P_2O_5 , K_2O as in 'B' making allowance of these F.Y.M.	11.0	17.9
D. Castor cake 60 lbs. N P K same as in B making allowance for these in cake	18.3	21.6
Mean	14.5	19.5
Critical difference (5%)	1.89	4.27

It will be seen that wheat in the rotation with legume gave higher yield than without it. The response to application of nitrogen as ammonium sulphate and castor cake was more pronounced than with the same quantity of nitrogen as farm yard manure.

Building up soil fertility by growing phosphate manured berseem with guar in rotation.—Investigations on phosphate manuring of legumes and their role in building up soil fertility have provided useful information of practical value. Phosphate stimulates early growth of legumes and nodule formation is accelerated. Rotation followed was of berseem-guar-berseem-guar-berseem-guar-wheat. The experiment was begun in 1946-47. Phosphate at two levels, 50 & 100 lbs. P_2O_5 alone and in combination with 80 lbs. K_2O had been applied to berseem crop every rabi season. These results are given as under :—

TABLE V.

Yield of berseem fodder (Mds. per acre).

Treatments	Year of experiment		
	1946-47	1947-48	1948-49
A. No manure	515.5	577.6	552.1
B. Super @ 50 lbs. P_2O_5	583.2	645.1	755.7
C. Super @ 100 lbs. P_2O_5	586.0	641.7	748.8
D. Super @ 50 lbs. P_2O_5 + 80 lbs. K_2O as K/S	553.8	627.2	771.2
E. Super @ 100 lbs. P_2O_5 + 80 lbs. K_2O as K/S	553.8	627.2	739.4
C.D. @ 5%	104.8	48.7	92.0
'F' test	Not sig.	Significant	Significant

The phosphate manuring of berseem has shown a progressive rise in the successive years. The effect of potash combination has not been indicated. The effect of this rotation on wheat crop will be studied successively in 3-4 seasons from 1949-50 onwards.

An investigation on the effect of phosphate manuring of berseem to build up soil fertility for rabi cereal consisted of application of phosphate alone at two levels with and without nitrogen or potash. This experiment was started in 1946-47. The rotation adopted was Berseem (manured)-fallow-wheat-fallow-wheat. The results of the 2nd wheat crop are given below :—

TABLE VI.
Yield of wheat in mds. per acre.

							Yield
Treatments per acre applied to Berseem in 1946-47—							
A. No manure	..	..	..	..	..	..	18.1
B. Super @ 80 lbs. P_2O_5	..	..	..	..	..	..	20.1
C. Super @ 120 lbs. P_2O_5	..	..	..	..	..	..	24.0
D. Super @ 60 lbs. P_2O_5 + Pot. sulph. 80 lbs. K_2O	..	..	..	..	..	..	27.3
E. Super @ 120 lbs. P_2O_5 + Pot. sulph. 80 lbs. K_2O	..	..	..	..	..	..	21.4
F. Am. sulphate 30 lbs. N + super 60 lbs. P_2O_5 + pot. sulph. 80 lbs. K_2O	..	..	..	..	..	..	24.7
G. Am. sulphate 30 lbs. N + super 120 lbs. P_2O_5 + pot. sulph. 80 lbs. K_2O	..	..	..	..	..	..	21.5
H. Am. sulphate 30 lbs. N + super 60 lbs.	..	..	..	..	..	..	21.2
I. Am. sulphate 30 lbs. N + super 120 lbs.	..	..	..	..	..	..	19.7
J. F.Y.M. at 30 lbs. P_2O_5	..	..	..	..	..	..	23.0
K. F.Y.M. at 60 lbs. P_2O_5	..	..	..	..	..	..	21.3
Critical difference at 1%							6.58
Critical difference at 5%							4.93

The best results are obtained in treatment D while treatments C, F, H & K are very about to each other. The results from the whole experiment are being critically analysed and written up.

Effect of manuring berseem with and without potash and its residual effects on maize and wheat.—The experiment started in 1946-47. The rotation followed is berseem (manured)-maize-wheat-jowar. The first course of the rotation was completed in kharif 1948 and second cycle began in rabi 1948. The residual response of the N.P.K. fertilizers applied to be berseem in 1946-47 was not evident in yields of the jowar crop in 1948. The yields of berseem crop manured in 1948-49 are given as under :—

TABLE VII.
Yield of six cuttings of berseem in mds. per acre.

Main plot treatments per acre					Subplot treatments per acre			Average
					No man- ure	Pot. sul 40 lb. K_2O	Pot. sulph 80 lb. K_2O	
A. Am. phosphate 80 lbs. P_2O_5	..	..	..	..	860.6	872.1	912.2	860.4
B. Am. phosphate 160 lbs. P_2O_5	..	..	..	..	895.8	943.6	848.5	917.2
C. Super 80 lbs. P_2O_5 + Am. sulph. N as in 'A'	..	..	..	..	859.6	867.9	834.3	854.0
D. Super 160 lbs. P_2O_5 + Am. sulph. N as in 'B'	..	..	..	..	916.5	965.6	918.0	933.4
E. Super 180 lbs. P_2O_5	..	..	..	..	751.7	810.7	776.6	779.7
F. Super 160 lbs. P_2O_5	..	..	..	..	835.2	850.8	859.5	848.5
G. No manure	..	..	..	..	331.8	354.6	398.6	361.7
Average	..	..	..	..	778.7	809.3	792.5	

Critical difference at	1%	..	..	..	} 103.23 for main plot treatments only.
	5%	..	..	..	

Results :— D, B, A, C, F, E, G @ 1% level of significance.

D, B, A, C, F, E, G @ 5% level of significance.

The difference amongst the main plot treatments were significant. Super at both levels responded by giving high outturns of berseem fodder, the differences in yield between Control and 80 and 160 lbs. P_2O_5 treatments being 418.0 mds. and 486.8 mds. respectively and the differences between the two phosphate treatments being not significant. The yields with Amm. phos. were comparable at both the levels to a mixture of ammonia sulphate and superphosphate. The enhanced yield with 100 and 200 lbs. nitrogen doses being 77.5 mds. and 76.8 mds. respectively. Dressing of 40 and 80 lbs. of K_2O applied as potassium sulphate have enhanced yields by 10.6 mds. and 13.8 mds. respectively. These differences were not significant.

Phosphate response was indicated in the experiment at both the levels. But the difference in yield between the two doses was not significant. It is further evident that the application of nitrogen together with phosphate exhibited response. Application of potash at both levels indicated small decrease in yield of the crop, though the differences over no potash treatment were not significant.

Effect of low doses of phosphate on berseem and building up of soil fertility.—The first cycle of this experiment was started in 1941-42. Three crops of berseem differentially treated as indicated in Table VIII below with three unmanured crops of cowpeas in kharif in each year were followed by wheat crop in 1944-45. The experiment was continued in two rotations (a) Cowpeas-wheat and (b) fallow-wheat till 1947-48. Direct response in yield of berseem fodder were similar to that indicated in table VIII. No effect was noticed on cowpeas. In case of wheat significant increases in yield over control were obtained with 64 lbs. P_2O_5 applied as super, F.Y.M. or in combination of both. This is the second cycle of the series and had been laid down on a poor field specifically selected for the purpose. The results of the experiment are given in table VIII.

TABLE VIII.

Yield of berseem green fodder in mds/acre (total of 3 cuttings).

Treatments per acre								Yield in mds.
A. F.Y.M. @ 16 lbs. P_2O_5	..	..	..	..	..	..	..	196.5
B. F.Y. M. @ 16 lbs. P_2O_5	..	..	..	..	..	..	..	298.3
C. F.Y.M. @ 64 lbs. P_2O_5	..	..	..	..	..	..	..	348.6
D. Super phos. 16 lbs. P_2O_5	..	..	..	..	..	..	..	211.0
E. Super phos. 32 lbs. P_2O_5	..	..	..	..	..	..	..	271.6
F. Super phos. 64 lbs. P_2O_5	..	..	..	..	..	..	..	348.2
G. Super phos. 8 lbs. P_2O_5	..	..	..	..	..	..	..	224.2
H. Super phos. 8 lb. P_2O_5 + F.Y.M. 8 Lbs. P_2O_5	..	..	..	..	..	..	..	272.6
I. Super phos. 8 lbs. P_2O_5 + F.Y.M. 24 Lbs. P_2O_5	..	..	..	..	..	..	..	405.7
J. F.Y.M. @ 8 lbs. P_2O_5 + super @ 24 Lbs. P_2O_5	..	..	..	..	..	..	..	276.9
K. F.Y.M. @ 8 lbs. P_2O_5 super @ 56 Lbs. P_2O_5	..	..	..	..	..	..	..	366.3
L. No. manure	..	..	..	..	..	..	..	127.7
Critical difference	..	..	..	..	..	..	..	42.96

Best responses in fodder yields were obtained with doses of 64 lbs. of phosphate, whether applied as super, farm yard manure or combination of the two.

TABLE IX.

Yield of berseem in maunds per acre.

			Doses of phosphate lbs. per acre				
			0	16	32	48	64
Observed mean response	..	..	127.7	214.0	279.8	..	367.2
Calculated Response	..	..	127.7	214.0	279.8	330.0	368.2

Soils have shown response to successive application of phosphates.

Phosphate manuring of berseem with and without nitrogen and potash with cotton and maize in rotations.—This experiment started with berseem in rabi 1946-49. The treatments are given below: The after effects are to be studied on maize and cotton grown in rotation with berseem. The rotation followed in the first six replications (1-6) is berseem-maize-berseem-cotton; while in the next 7-12 replications it is berseem-cotton-berseem-maize rotation. The yields of berseem green fodder from the experiment is reported as under :—

TABLE X.

Yield of berseem green fodder in mds. per acre (total of 6 cuttings).

Treatment per acre							Replica- tions 1-6	Replica- tions 7-12	Mean
A. No manure	..	..	..	..	..	..	521.9	469.7	495.6
B. 120 lbs. P_2O_5 as superphosphate	..	..	..	..	..	..	724.1	698.9	711.5
C. 120 lbs. P_2O_5 as superphosphate + 120 lbs. K_2O as pot. sulph.							718.4	610.7	664.5
D. 120 lbs. P_2O_5 as Amm. phos. (which also contain 100 lbs. N)	..	..	..	..	..	..	832.3	825.1	843.7
E. 90 lbs. P_2O_5 as super + 30 lbs. P_2O_5 as Amm. phos. (which also contains 25 lbs. N)	..	..	..	..	..	..	773.4	746.4	759.5
F. 60 lbs. P_2O_5 as super + 60 lbs. P_2O_5 as Amm. phos. (which also contains 50 lbs. N)	..	..	..	..	..	..	813.1	762.2	787.6
G. 120 lbs. P_2O_5 as Amm. phos. (which also contains 100 lbs. N) + 120 lbs. K_2O as sulphate of potash	..	..	..	..	..	..	889.5	815.8	852.6
Critical difference @ 1%	..	..	..	..	..	..	121.83	144.55	
5%	..	..	..	..	..	..	96.46	107.33	

Manuring of berseem with phosphate has given an increased yield over control. Addition of N at 100 lbs. per acre to phosphate has further increased the yield of berseem in both rotations as compared to phosphate treatments only.

Response of various legumes to fertilizer treatments and comparison of after effects with direct manuring of cereals.—The experiment was started in 1946-47. The Rabi legumes in the experiment were senji, methra and berseem for fodder and gram and peas for seed. These legumes are manured with phosphate with and without nitrogen and or potash showed that there was no

difference of this indirect manuring maize and wheat in 1947-48 whereas in both cases, direct application of nitrogen showed its effect by increasing the yield of the crops. The experiment is being repeated and the results are as under —

TABLE XI.

Yield of rabi legumes in mds. per acre.

Treatment per acre	Peas N.P. 29	Gram N.P. 58	Fodder	Senji Seed	Fodder	Seed	Berseem (Green fodder)
A. No manure to legumes & Am. sulph. 40 lbs. N to be applied to cereals in 1949-50	26.5	12.6	65.0	5.5	208.4	6.9	556.5
B. Super 120 lbs. P ₂ O ₅ to legumes-P	29.6	11.6	110.9	8.6	264.3	8.8	703.8
C. B+Am. sulph. 40 lb. N to legumes -NP	29.4	13.1	98.9	8.1	243.3	9.0	766.0
D. B+Pot. sulph. 80 Lbs. K ₂ O to legumes PK	28.5	12.3	82.2	8.7	241.2	8.4	810.2
E. C+Pot. sulph. 80 Lbs. K ₂ O to legumes NPK	31.2	11.2	126.4	9.4	265.7	10.0	775.2
F. No manure to legume or cereal	26.4	12.2	59.4	5.4	202.3	4.8	563.7
C.D. at 1%	3.65	Not sig.		1.62	27.59	2.05	140.21
at 5%	2.69			1.19	25.22	1.50	102.80

Different forms of phosphates.—Different forms of phosphatic fertilizers are now available for use as manures. To test their comparative response an experiment was laid out in the *rabi* season. They consisted of Triple Superphosphate, Ammophos, Renohyperphos, Bonemeal, Bonemeal sulphur compost, Rock phosphate and Trichy nodules. The yield of fodder by application of a dose of 80 lbs. P₂O₅ in each case was compared to no manure and ammonium sulphate containing 60 lbs. of nitrogen corresponding to N content of Ammophos. It was observed that ultimate yield was the highest with Ammophos and next highest was from triple superphosphate treatment. An average yield of 1000 mds. of green berseem fodder was obtained from the experiment.

Placement of fertilizers.—In recent years considerable attention has been paid to the study of placement of fertilizers. This is necessary for better utilization of nutrients and economy. A fertilizer placement experiment was started in 1947-48 and encouraging though not significant results by placement were reported last year. The experiment was repeated on the LSICAR

same site this year and treatments were replicated in the same plots. The results of the experiment for 1948-49 are reported below :—

TABLE XII.

Yield of green berseem in mds. per acre.

Subplot treatments	Sown and manured broadcast	Main plot Sown 1" apart and fertilizer placed	treatments Sown 6" apart and fertilizer placed	Average
No manure	523.3	523.3	440.2	495.6
Super 80 lbs. P_2O_5	724.8	764.3	723.6	737.5
Super 80 lbs. P_2O_5 + pot. sulph 60 lbs. K_2O	768.3	719.4	755.1	748.2
Super 80 lbs. P_2O_5 + Am. sulph. 40 lbs. N	752.8	714.1	750.4	741.6
Am. sulph. 40 Lbs. N + Pot. sulph. 60 lbs. K_2O + Super 80 lbs. P_2O_5	759.4	715.9	797.6	758.3
Average	706.0	687.6	695.1	..
C.D. @ (5%) (1%)	66.42 89.57	C.D. for main plots and interactions is not significant.		

From the results it appears that placement did not indicate special advantage in enhanced yield of the crop. The fertilizers showed their effect. Application of potash or nitrogen made little difference in the yield of the crop. Application of 200 lbs. dose of superphosphate significantly enhanced the crop yield. Both years' results have shown that phosphate when placed for Berseem manuring has not given significant response.

(ii) A preliminary experiment on peas was conducted. The fertilizers, consisting of 30 lbs. and 40 lbs. doses of P_2O_5 were placed at $3\frac{1}{2}$ and $4\frac{1}{2}$ inches depths. Indications were that deep placed fertilizer ($4\frac{1}{2}$ inches) resulted in better yield than fertilizer broadcast in the plots.

Effect of sannhemp as green manure, sown in situ and buried and brought from outside, in combination with different fertilizers.—The most common green manure crop in India is sannhemp. It is a legume and produces an abundant growth under rainfed condition within a short period of six weeks. The details of the experiment and the results are given below. The rotation will be wheat-maize-wheat.

TABLE XIII.

Main plot treatments per acre	Subplot treatment per acre				Average
	No fertilizer	Am. sulph. 40 lbs. N sowing time of wheat	Super 80 lbs. P_2O_5 at burying sannhemp	Am. sulph 40 lbs. N sowing wheat + super 80 lbs. burying Sannhemp	
A. No green manure	11.6	15.8	11.1	21.8	15.1
B. Sannhemp sown <i>in situ</i> and buried	18.9	18.8	20.2	25.4	20.8
C. Sannhemp brought from outside and buried 200 mds. per acre	13.9	17.4	10.7	24.8	16.6
D. Sannhemp brought from outside, composted and later buried at 200 mds. per acre (green weight)	14.0	13.9	17.1	25.5	17.7
Average	14.4	16.5	14.8	22.2	..
C.D. @ 5%	2.54	Interaction not significant.			

Sannhemp grown *in situ* and buried was superior to either sannhemp brought from outside and buried or sannhemp composted and later on applied to the field. The results also indicated that composted material when applied gave significantly greater yield than no green manure treatment. Amongst the subplots N.P. treatment gave the highest yield, but was not significant.

Studies on the effect of different fertilizers on the associated growth of cereals and legumes.—Wheat and gram were selected for this experiment which in its present form started in 1948-49. The results are shown below :—

TABLE XIV.
Crop yield in mds. per acre.

Treatment per acre							Wheat and gram mixture	Wheat C.518	Gram NP 58
A. No manure	..	..	..	..	..	..	21.5	23.6	10.7
B. Am. Sulph. 40 lbs. N.	..	..	..	..	..	..	27.6	26.9	10.2
C. Super 60 lbs. P ₂ O ₅	..	..	..	..	..	..	27.8	28.2	13.1
D. Am. sulph. 40 lbs. N super 60 lbs. P ₂ O ₅	..	..	..	..	..	..	30.4	31.3	15.4
E. Super 60 lbs. P ₂ O ₅ pot sulph. 60 lbs. K ₂ O	..	..	..	..	..	..	23.5	25.9	13.6
F. Super 60 lbs. P ₂ O ₅ + Pot. sulph. 60 lbs. K ₂ O + Am. sulph 60 lbs. N	..	..	..	..	..	..	28.9	34.5	7.3
Critical difference (5%)							3.96		

The experiment is being continued.

Date of sowing, depth of seeding and spacing of rows influence, the incidence of gram wilt and thereby yield of crop.—Gram wilt is soil borne disease. Experimental work in the Division of Mycology had indicated that late sowing of gram reduced the incidence of wilt. With a view to investigate this problem and study other related factors, a cultural experiment was started in the year 1947-48. The difference of yield due to treatment was not significant. The incidence of wilt was low during the year.

Seed size, Spacing of seed pieces, and potash influence potato yields.—An experiment to study the effect of size of tuber, spacing and application of potash was continued during this year.

Effect of depth of cultivation, placement of phosphate, and time of application of nitrogen on cane and sugar yields.—Sugarcane crop is bulky crop and is responsive to intensive cultivation and manuring. With the object of working out the effect of cultural treatment an experiment was laid out in February, 1948. The treatments under test are ploughing with *Desi* plough as against ploughing with tractor plough at a depth of six inches and ploughing to a depth of 10 inches. The two other treatments are placement of Super versus broadcast superphosphate and application of full dose of nitrogen at planting as against applying half dose at planting and half at earthing up. Results are not yet available.

Control of weeds in wheat field.—This collaborative experiment was undertaken with Botany Division. In wheat several board leaved weeds spring up. Of these, *Carthamus* *sp.* come up in abundance with cereal crops. To keep them in check the common practice of hand weeding is adopted. In recent years considerable advance has been made in evolving chemical agents as weed killers.

One of the proprietary products (Methoxene) with which a field experiment was conducted has given encouraging results which are reported as under :—

TABLE XV.
Effect of spraying Methoxene on wheat field.

Main plot treatments	Sub-plot treatments				Average
	A No weeding	B Weeding with hand	C Spraying Methoxene once after sowing	D Spraying Methoxene twice after sowing	
O—No spraying with 'Methoxene' before prep. cultivation ..	11.6	18.9	15.6	14.1	15.0
S—Spraying 'Methoxene' before preparing cultivation ..	14.9	15.6	15.7	14.8	15.3
Average	13.2	17.2	15.6	14.4	
S.E. for main plot treatments					± 2.40 mds./acre.
5 per cent. C.D. for sub-plot treatments					2.77 mds./acre.

Results .—Differences between main-plot treatments are not significant.
Differences between sub-plot treatments are significant at 5 per cent. level.

Differences between Interactions are not significant.

Weeding by hand gave the highest yield which was significantly greater than no weeding treatment. There was no significant difference between treatment C. & D. The interaction was also not significant.

Effect of seed rate on wheat yield on medium loam soils.—An experiment to determine the optimum seed rate requirements of wheat on medium loam soils with an assured water supply was conducted. The normal seed rate used for drilling is 80 lbs. per acre. The object of the experiment was to study whether seed rate could be reducing the yield of crop. The results are given as under :—

TABLE XVI.
Seed Rate Experiment.

	Seed Rate per acre				General mean	Critical Difference at P=0.05
	50 lbs.	65 lbs.	80 lbs.	95 lbs.		
Mean yield-Mds. per acre ..	24.1	28.6	28.0	31.6	28.0	3.7
Per cent on control ..	100	118.8	116.2	131.3	116.2	15.4

Differences amongst 65, 80 and 95 lbs. seed rates were not significant but all these were better than 50 lbs. seed rate.

Selection of sugarcane varieties superior in Agronomic characters and quality of juice.—As part of teaching and research programme in sugarcane agronomy varietal selection work was taken up from the crop season 1948. In the observation plots, some of the varieties were showing promise and amongst them there were sufficient material of a few to start a varietal trial. These varieties were Co. 537, Co. 620, Co. 621 and Co. 622. These varieties had been released from Coimbatore in 1944, and were under observation and multiplication. To test their performance these were planted against the

standard varieties Co. 312, Co. 421 and Co. 453 which are already in cultivation in the North India cane tract. The results have indicated that highest yield of 654.3 mds. was given by variety Co. 312. Cane yields of varieties Co. 453 and Co. 537 were comparable. In recoverable commercial cane sugar per cent varieties Co. 621, Co. 622, Co. 453 and Co. 421 were comparable, average value being 12.5 per cent. Similarly in the C.C.S. per cent value of Co. 312 was comparable to Co. 620. Variety Co. 537 gave the lowest C.C.S. per cent value. The thickest cane in the series was Co. 453 of which the average thickness was 0.867 inches compared to 0.750 inches of Co. 312, 0.752 inches of Co. 620, 0.736 inches of Co. 537, 0.799 inches of Co. 421 and 0.800 inches of Co. 622. The thinnest cane in the series was Co. 621. Thus statistically the thickness of varieties Co. 622, Co. 421, Co. 620 and Co. 312 was comparable while the thickness of 1st three was significantly greater than Co. 537 and Co. 621. A highly significant coefficient of correlation between tillering and yield of varieties was observed.

Observations on lodging in some new wheat varieties.—Five strains out of the several new ones which partially combine in them resistance to rust and other desirable characters were tested against three standard wheat varieties. The varieties thus, under test were Co. 518, N.P. 125, N.P. 165, N.P. 720, N.P. 733, N.P. 762, N.P. 770 and N.P. 775. None of the varieties lodged in the trial whether it was manured at the rate of 60 lbs. N and 80 lbs. P_2O_5 as ammonophos per acre or unmanured. Under manured conditions N.P. 165 gave the highest yield which was significantly greater than N.P. 125, N.P. 733, N.P. 762 and N.P. 770. Under unmanured conditions the outturn of N.P. 720 was the highest. Under both sets of conditions N.P. 720 yielded the lowest. It appears to be a late manuring variety.

Berseem varieties : Their fodder value and seed setting capability.—Four varieties of berseem under test are (i) Peshawar acclimatized, (ii) IOC (Botany Division Selection), (iii) Miscawi (Egyptian) and (iv) *Fahli* (Egyptian). Of these IOC strain is selection out of Peshawar acclimatized. This variety gave higher seed yield than others, but the differences were not significant. The two Egyptian varieties have not proved superior to Peshawar acclimatized either in fodder or seed yield. In fact Peshawar acclimatized was significantly superior to other three varieties in fodder yield.

The establishment and testing of grass and legume species of exotic and indigenous origin.—The collection of grasses both indigenous and exotic were further augmented by 11 thus making up 52 indigenous and 20 exotic grasses. American varieties of sweet and Tift Sudan grass and *Phalaris minor*, a promising winter annual were multiplied. *Stearia palmaefolia* from Assam was found to possess higher nutritive value than the known indigenous grasses. It responded to nitrogen and phosphate manuring and gave 30 per cent. more yield than 20:80 N.P. mixture. Legume nursery consisted of 33 exotic and indigenous legumes. Ten promising legumes including vetches, Bur Clover, Sweet clovers, subterranean clovers, Red clover, white clover, soyabeans, lupins, desmodiums, and kudzu vine are being multiplied. The following showed promise :—

Vetches.—They appear to have a good future both as winter fodder and as well as component in seed mixture. Purple vetch (*Vicia autoropurea*), hairy vetch (*V. villosa*) amongst exotic vetches and *Vicia hirsuta* among the indigenous ones have been found promising.

Medics.—Bur clover (*Medicago hispida*) and barrel clover (*Medicago denti culata*) indicated good performance.

Sweet Clover.—Huban clover, Annual sweet clover and evergreen showed considerable promise.

Subterranean clover.—These have revolutionised the agriculture in Australia. Four strains under observation were Baeceus Marsh, Mid-season and Mt. Barker. All these indicated late vigorous growth.

Red and white clovers.—These clovers largely find a place in seed mixtures in range lands in other countries. Of these Red clover (*Trifolium pratense*) was found to grow well under Farm conditions.

Soyabeans.—Five promising American soyabean varieties were multiplied. Fodder and grain yield trials have been laid down for 1949-50.

Lupins.—Amongst blue and yellow lupins the former showed a very good growth. Seed of blue lupins is being multiplied.

Desmodium.—*Desmodium diffusum*, an indigenous species, was found to be promising. It is under multiplication for future trials.

Kadzu vine.—It has been extensively employed for checking soil erosion by plugging gullies in America and elsewhere. A single plant of *Pueraria thumbergiana* planted on 10-8-45, by its profuse growth, covers over 1/15th acre area. Flowering and pod formation was observed in September and again in April, 1949. Investigations on factors responsible for seed formation have been taken up.

Improvement of grasses and legumes species from the standpoint of building up soil fertility providing pasturage and use in soil conservation.—It is being increasingly realised that grasses and legumes play a prominent role in bringing about favourable changes in soil structure, addition of organic matter and nitrogen, checking erosion of top rich soil and providing protein rich palatable pasturage. In India most tracts of cultural waste lands are being rapidly eroded. They require such grasses which will stand the impact of erosion and yet be nutritious for feeding the cattle. There are millions of acres of land which have gone out of cultivation because of weed infestation. The introduction of grass-legume mixtures should prove of value for improving the land and quality of grazing for cattle.

Some of the promising fodder grasses are listed below :—

1. *Chloris gayana* (St.)
2. *Pennisetum orientale*
3. *Panicum repens*
4. *Dichanthium annulatum*
5. *Themeda tremula*
6. *Chrysopogon montanus*
7. *Themeda anathera*
8. *Phalaris tuberosa*.

Residual response of Rhodes grass—lucerne hay.—The lay of Rhodes grass—lucerne was started in 1945. This was cleared off in the spring of 1948 when maize was sown. To start with the ley had quite a high proportion

of lucerne. As time elapsed the grass replaced it in succession. At the end of three years the lucerne had been suppressed to a very large extent. NP & NPK treatments exhibited beneficial effects on total yield of ley, nitrogen, phosphate, and potash being applied at the rate of 80 lbs., 80 lbs., 80 lbs. per acre. The three years Rhodes grass-lucerne hay was ploughed down and was followed by maize and wheat in succession to study effect of hay. The late sowing of maize owing to continuous rains affected adversely the growth of crop and had to be cut for fodder. Analysis of wheat yield from differentially manured ley plots did not differ significantly. From the general low level of yields it appears that the yields are not markedly influenced in the first year after ley. Sahirana (1940) recorded that residue decomposition was fairly rapid particularly in the upper layers but is not complete until about 18 months after ploughing and he considers it a possible reason for low yields after ley for the first 18 months.

Investigations on seed mixtures and Pasture Improvement.—For seasonal production of pasture grasses with a view to obtain nutritious fodder throughout a year a scheme of seed mixture was put into operation. Out of 23 seed mixtures under observation, in the first year, two mixtures have been found satisfactory as maintaining continuity of balanced fodder throughout the year under irrigated conditions.

Mixture No. 1

Grasses

Chloris gayana

Alysicarpus rugosus

Phalaris minor

Legumes

Vicia hirsuta

Mixture No. 2

Grasses

Dichanthium annulatum

Pennisetum orientale

Alysicarpus rugosus

Legumes

Vicia hirsuta

Lucerne

In the second mixture *Dichanthium annulatum* and *Pennisetum orientale* replaces Rhodes grass (*Chloris gayana*) which is the standard pasture grass at the farm and lucerne supplements the legume *Vicia hirsuta*. These mixtures form the basis of further experiments on extended scale proposed for 1949-50.

Collaborative trials on grasses and legumes have been taken up in the different Provinces and States. They include grasses and legumes which will yield valuable nutritious fodder during all the seasons. The selection of grasses for collaborative study has been done on the basis of experimental work at the Institute and agro-climatic conditions of different tracts in India.

Saharina (1940)

Quoted by R. O. Whyte "Alternate Husbandry Imp. Bureau of Pastures & Forage crops Joint Publication No. 6.

Integrated approach to increased production of food, feed and fodder on small agricultural holdings.—The problem of a peasant is to make a living by maximum production out of his industry. The investigations in progress are an attempt to make an integrated approach to the problems of crop husbandry with special reference to small farmers. The sizes of holdings vary between 6-8 acres. This area is utilized to grow cereals, pulses, cash, feed and fodder crops enough for balanced feeding of the family and the stock. Thus two sets of holdings have been laid down, namely :—

- (a) *Green manure holdings.*—The size of these holdings is 8-acres each. The cropping programme is planned to maintain a family and work cattle. Different intensities of green manuring supplement the F.Y.M. available from work cattle, to the extent of green manuring 50 per cent and 66 per cent of the *rabi* cereal area in the preceding season in two of the three holdings. The third 8-acre holding serves a standard for comparison. Eighth years' data have revealed that the practice of green manuring should be adopted to keep up high level of soil fertility and remuneratively augment the cereal, feed, fodder, roughage and cash crop yields.
- (b) *Cultivator holdings.*—Five 6-acre holdings were planned in 1947-48 to compare the relative merits of alternate crop rotations for maintaining soil fertility with and without application of phosphate to the legumes in the rotations. These are mixed farm holdings, three under irrigation and two under barani conditions. Besides, maintaining the records of crop yields, cost accounts are kept separately for each of the holdings.

The results of 2nd year of working of 6-acre holdings indicated that on irrigated holdings fodder supply, roughages and feeds were in excess of requirements. Cereals were sufficient but outturn of cotton did not come up to expectation. The yield of sugarcane was fairly good. Level of yield on barani holdings was low in the *kharif* season but returns of *rabi* crops were quite high. On the whole, they were not sufficient for meeting the requirements of farmer's family and stock maintained thereon.

8. Cattle Breeding and Management Section.

As part of the Mixed Farming programme importance of cattle improvement for draught and dairy purposes is of prime importance. A foundation stock of Sahiwal cows formed the nucleus for breeding and study of management practices. In 1936-37 the Tharparkar herd, a dual purpose cattle, at Karnal was taken over to improve on the lines initiated in Sahiwal herd at Delhi. The programme of work is identical at both the stations.

Line breeding and selection for improving dairy qualities of Sahiwal cows.—The strength of cows at the close of the year was 145. Fifty four male and sixty nine female calves were born. Thirty eight matured to be cows. Out of these 13 heifers gave over 6000 lbs. of milk. The average age of calving was 2 years 7 months and 14 days. Heifer Inlakhir yielded 13841 lbs. of milk in a continuous lactation of 620 days. Heifers Vilkrani, Wafehrana and Afobiaam did about 8,000 lbs. in 1st lactation. The milking average of heifers for the year was 18.1 lbs. per cow per day.

Out of the adult cows Tamili in her sixth lactation did 13,004 lbs. in 10 months lactations. Gatibi a daughter of Tamili yielded over 10,500 lbs. in third lactation. There were five other adult cows who gave milk yield exceeding 8,000 lbs. The milking average per adult cow per day was 21.3 lbs. which

was better by 1.0 lb. than last year. Over 70 per cent of milch stock gave lactation yield over 5,000 lbs. per lactation.

There was a great demand for young breeding stock from States. This demand was partially met by sale of 39 young bulls from the herd. The total dairy stock on hand at close of the year was 373 animals.

Early maturity experiments to reduce calving age of heifer and service age of young bulls.—Average birth weight rate of cow calves was 54.0 lbs. They increased in weight at the mean rate of 0.8 lbs. per day. Only nine heifers mated at an age over two years. The remaining 29 heifers conceived at the age of 1 year 8 months and 6 days when their mean body weight was 623.3 lbs. At calving they weighed 788.0 lbs. The remaining 9 heifers conceived at an average age of 2 years 2 months and 11 days with a body weight of 686.2 lbs. and average weight at calving of 808.2 lbs. Thus early maturity in no way affected the milk yield of heifers.

Pre-calving milking to induce early heavy flush and develop milk temperament.—The procedure of precalving milking was further standardise. Average period which was considered satisfactory to induce early flush was about 10 days in adult cows and about 15 days in heifer. Animals in poor state of health adversely reacted to premilking. It means that down calvers should receive proper attention.

Four-time milking, persistency, disease incidence.—One of the factors contributing to high milk yield in the herd is the four times milking of the cows. Statistical analysis of the data have revealed that about 40 per cent increase in milk yield during the period 1932-40 may be attributed to it. It was noticed during the year that any shortage in legume fodder adversely affected the health of milch stock, four-times milked during the day. Berseem during the winter and cowpeas during summer are, therefore provided to the cows to maintain them in high production. Stoppage of mineral feed had bad effect on health of animals, when 17 animals suffered from *hypocalcaemia*, 4 from mineral inbalance and three from debility. These animals were milked at reduced number of milkings. Four clinical cases of John's disease were segregated of whom two died. Experiment of 4 time milking suffered a setback due to attack of Foot and Mouth disease in which 332 animals were involved. Several cows were put on reduced number of milkings. It was also observed that animals milked four-times had good persistence and usually completed 10 months lactation.

Weaning, standardized practice of calf rearing, and reduced calf mortality.—Weaned cows responded favourably to the standardised practice of calf rearing. Milk fat was reduced from 4.95 per cent to 3.5 per cent by mixing separated milk. Boiled and cooled milk was fed to calves starting in the 1st week to 1/10 the body and gradually increasing to a maximum in the eighth week, when the calves were given 0.9 lbs. per day up to eight months. Main cause of mortality in calves was Foot and Mouth disease which brought about death of 8 calves. Prophylactic measures brought the disease under check. The mortality among the calves below two weeks age from pyosepticaemia was much reduced and in fact brought under control by injection of dam's blood serum drawn immediately after calving. Calves brought up on standard rearing practices suffered less from stomach ailments such as diarrhoea, obstructive colic, coccidiosis, constipation, indigestion, etc. But for the mortality due to foot and mouth disease rearing practices the mortality amongst calves would have been very low.

PROGRAMME OF WORK FOR 1949-50.

AGRONOMY.

1. *Soil fertility problems.*—(A) *Manurial experiments on cereals and crops in rotation.*—

- (i) Nitrogenous manures and fertilizers—Experiments to test the relative value of nitrogen in organic and inorganic manures and also responses of their combinations on wheat and maize.
- (ii) Phosphatic fertilizers—Experiments with the different forms of phosphatic fertilizers to study their responses on *Kharif* and *Rabi* legumes and after effects on cereals following the legumes.
- (iii) Nitrogenous and phosphatic fertilizers—To study the relative merits of different types of nitrogenous and phosphatic fertilizers at ten experimental stations all over India.
- (iv) Nitrogenous, phosphatic, potassic and calcium fertilizers—Experiments to study the effect of these each at three levels and in all possible combinations on the yield of wheat.
- (v) Green manures—Experiments with different legumes as green manures with and without fertilizers on wheat. Experiments to study the effect of green manuring when the crop is sown *in situ* and brought from outside.
- (vi) Permanent Manurial and New Manurial experiments at Pusa—The experiments will be conducted under the supervision of this Division.

(B) *Placement of fertilisers in row crops.*—To effect economy in the quantity of fertilizer used and their better utilization by field crops.

(C) *Mixed cropping of Cereals and legumes.*—To study the possibility of maintaining soil fertility by growing a mixture of cereals and legumes under different fertiliser treatments.

(D) *Mixed Farming.*—To obtain maximum overall yields which a cultivator is likely to get from holdings of 6 acres under irrigated and rainfed conditions designed to meet the requirements of his family members and cattle and produce milk for cash sale.

2. *Irrigation experiments.*—To study the irrigation interval effect on various crops.

3. *Cultural experiments.*—On sugarcane, grass and potato to investigate proper spacing of row crops ; planting distance of potatoes, depth of sowing gram, and different preparatory tillage treatments on sugarcane.

4. *Varietal yield trials.*—Experiments will be conducted with improved varieties of different crops such as sugarcane, wheat, tobacco, potatoes, sweet potatoes and tomatoes.

5. *Agrostology.*—To produce high yielding and palatable fodder grasses and legumes for cattle ; increase the productivity of natural grasslands ; work out suitable seed mixtures of grasses and legumes for pasture ; evolve a suitable system of ley farming.

Cattle breeding and Management.

1. Line breeding and selection for improvement of milk yield of Sahiwal cattle.

2. Handling of the stock for the development of milk temperament.
3. Feeding of stock on balanced rations for growth, early maturity and high milk production.
4. Four times milking as a means of stimulation for the production of high yield.
5. Pre-milking as a means of stimulation for milk production, to train heifers to milk before calving and to prevent udder trouble.
6. Calf rearing on standardised milk ration containing 3.5 per cent butter fat.
7. Early maturity treatments to test bulls for their transmitting capacity of high milk yield quality at an early age.

REPORT OF THE DIVISION OF BOTANY

PLANT BREEDING AND GENETICS

Breeding for Rust Resistance in wheat.—Work on this project was commenced at Simla in 1935 under a scheme financed by the Indian Council of Agricultural Research. The breeding part is done in the Division of Botany and the testing part under Dr. K. C. Mehta of Agra University. The scheme is limited to the hill wheats on the basis of Dr. Mehta's work that the wheat rusts over-summer in the hills and that the latter are therefore the foci of infection for the wheat crop in the plains.

Wheat strains resistant, separately, to the physiologic races of the three rusts occurring in India have been built up. These represent an intermediate stage in the programme which finally aims at synthesizing wheats possessing resistance simultaneously to the three rusts. The strains were put under small-scale trials at several places in the hills to see whether any of them could be of some immediate use to the farmer.

Many of the strains retain their resistance to the particular rust against which they were bred. Those resistant to brown and yellow rust, however, go down badly to black rust; in spite of this, they have given good yields at Simla comparing favourably with the local hill wheats. Some of the black rust resistant strains, however, appear to possess a degree of resistance to the other rusts also; their yields are, however, lower, and further yields trials are necessary before they could be recommended to farmers. Some of the black-rust resistant strains did not maintain their resistance at some centres. The matter is under investigation. A double cross has been made on a large scale, to combine high resistance to the three rusts with desirable agronomic characters. The hybrid cultures were in the F_6 stage and some of them appear to be approaching purity in respect of the major characters. Selections have been made in these for next year's work. Whilst hardly any plants were completely free from rust, a sufficient number of them had the merest trace of one or two rusts and appeared to be of practical usefulness.

Wheat varietal trials.—Twelve recently-evolved N.P. strains of wheat were again under trial, this time at 26 different stations representing the important wheat-growing tracts of India, with the cooperation of the Provincial and State Departments of Agriculture. As in the previous years these strains did very well at many places. N.P. 710, 715, 760, 775, did well in certain localities in the East Punjab, in Delhi and the west of the Western region of the U.P. and N.P. 710, 715, 760, 720 and 758 in the Rajputana area in the same region. In the Central region represented by Kanpur, Allahabad and

Attarra, N.P. 710, 715, 758, 764, 775 did well, whilst in the Eastern region (east U.P., Bihar, Orissa, West Bengal) the performance of N.P. 710, 718, 737, 760, 761, 762, 775 was better than others. In the C.P. and Indore area N.P. 710, 715, 718 and 758 did fairly well and N.P. 710, 715, 718 and 764 did well in part of the Bombay area. In many areas some of the N.P. varieties showed considerable degree of resistance to one or other of the rusts especially to brown rust.

Varietal response of wheat varieties to manures.—This year five varieties and a mixture of all these were tested at three levels of fertility in addition to the no manure treatment. The last year's observations that the manurial treatments had a significant effect on the yields of varieties was confirmed. Statistically, the maximum dose of manure, half maximum dose, only nitrogen, control. The differences between the varieties are insignificant. The results are summarised below :—

Average yield in maunds per acre.

Varieties	Manurial Treatment				Mean
	Maximum dose of N.P. and K.	$\frac{1}{2}$ Maximum dose of N.P. & K. K.	Only N.	Control	
C. 518	28.82	24.70	22.43	21.23	24.28
N.P. 165	33.10	29.80	24.54	20.42	26.97
N.P. 125	30.32	25.19	19.17	18.82	22.13
N.P. 710	31.52	29.85	26.82	23.08	27.82
N.P. 761	30.01	23.02	20.15	15.17	22.09
Mixture	28.93	28.50	25.08	23.50	26.50
Mean	30.45	26.84	23.02	19.54	24.96
S. Em for varieties	1.16	S. Em for manurial treatments=0.69.			
C.D. at 5%	4.76	C.D. at 5% manurial treatments=1.99.			

Breeding rust resistant Linseed (Linum usitatissimum L.).—Breeding for resistance to rust (*Melampsora lini*) was continued with the cooperation of the Division of Mycology. One hundred and one strains obtained from crosses made in 1933 between outstanding N.P. varieties, which are susceptible to rust and foreign varieties, which are immune to rust but which proved unsuitable for cultivation in India owing mainly to these being very late in maturity, were tested for the second year for their resistance to a number of spores of four physiological races of the rust so far found in India both in seedling and adult stages. The seedling and adult resistance tests were conducted in the Division of Mycology under laboratory conditions and the latter under field conditions in the Botany Division there being two replications.

78 strains were observed to be absolutely free from infection, 6 had slight infection and 17 had moderate infection. The results of tests in the Mycology Division were more or less in agreement with these results and with those of the previous year. The N.P. parental varieties, as also the control, N.P. 21, were heavily infected.

Tested at the Agricultural Substation, Karnal, under natural field conditions where the incidence of the disease is usually very heavy, only four out of the 101 were found to be infected. The control and the N.P. parents also had infection, whereas the foreign parents were free from infection.

Selection of strains combining rust resistance, and economically important characters was continued in the F_4 progenies of crosses between N.P. rust resistant strains and early maturing provincial types. A large number of promising plants have been selected for further work.

Thirty-five of the more promising strains out of the 101 strains were tested in some of the provinces and states. The results of trials in Hoshangabad (Central Provinces), Jullundur (East Punjab) and Chinsurah (West Bengal) which only were available so far showed that whereas the best local variety was infected with rust, all the 35 strains were free. At Jullundur and Chinsurah several of the rust resistant strains outyielded the control and a few even to the extent of 50 to 100 per cent. However, at Hoshangabad these strains did not fare well probably because of the short growing period, the rust resistant strains being late for this region. Moreover, the sowings were done very late.

The oil content of these strains as determined in the Division of Chemistry showed that many of them had a high oil content.

Breeding wilt-resistant Pigeon pea (Cajanus cajan (L) Millsp.).—The breeding for resistance to wilt (*Fusarium vasinfectum* Atk) and for other economically important characters was continued. In the Mycology Division tests were conducted under laboratory conditions. In the Botany Division the tests were conducted in an artificially infected field.

Twenty three strains from the old crosses (N.P. 51 $\times$ N.P. 24) and 33 cultures from crosses between N.P. 69 and Kanpur 132 were tested for their wilt resistance along with N.P. 69, a wilt susceptible type as control and further selections were made.

Breeding tomato varieties combining earliness, high vitamin content and improved flavour.—Varieties are not available in northern India which can give appreciable yields before the frost prevails and which also start bearing early in the season when tomatoes are generally imported into the parts of the plains. Breeding work has been undertaken some years back for evolving such varieties. A study of the available information revealed that the south American wild species, *Lycopersicon pimpinellifolium*, was a promising material worth utilising in this project especially as it has been successfully used in U.S.A. and Germany for producing early varieties.

It has been possible to isolate types earlier than the wild species. During the various stages of selection for earliness, tests were also in progress for vitamin and sugar contents. One of the sweet flavoured selections on analysis was found to contain 2.69 per cent reducing sugar (dry basis) which is about four times that of the common tomato. It may, however, be stated that it is only some of the small fruited selections which are sweet flavoured. The vitamin content was also found to be more in small fruited types. It has, therefore, not been possible to select a type combining large size, a high vitamin and sugar content. The earliness is sought for in the sense that the plants are capable of giving early crops if planted early i.e. in August. During the year under report about half a dozen selections were finally chosen and these are now under trial in the provinces.

A further collection of useful genetic stocks comprising wild species, subspecies and varieties of the common cultivated species was imported and studied. One of the wild species, *L. peruvianum*, was found to contain 92.5 mg. vitamin C per 100 gm. sample which is about three times that of tomato and about 30 per cent. more than that in *L. pimpinellifolium*. The chemical analyses including estimation of vitamin C content have been done in the Division of Chemistry.

Hybrid Maize.—This work is being done under a scheme financed by the Indian Council of Agricultural Research. Seeds of 111 indigenous varieties have been collected from different provinces and states in India, and of 20 exotic varieties from different places outside India. A brief summary of the frequency distribution of Indian varieties with respect to different characters is given below :—

Days to silking	No. of varieties	Plant height in inches	No. of varieties	Vigour index	No. of varieties	No. of good cobs per plant	No. of varieties	Ear length in inches	No. of varieties
40-42	1	90-110	7	5	28	0-0-5	4	4-4-9	7
43-45	9	111-130	4	4	45	0-51-1-0	51	5-5-9	26
46-48	22	131-150	17	..	..	..	..	..	..
49-51	8	151-170	30	3	26	1-01-1-5	36	6-6-9	41
52-54	20	171-190	35	2	9	1-51-2-0	3	7-7-9	26
55-57	26	191-210	11	..	..	..	..	8-8-9	9
		211-230	3	..	..	..	..	..	..

None of the foreign varieties was found to be as early as the earliest of the Indian varieties. The former silked from 47-58 days. Nearly 50 per cent of them were of poor vigour, although four of them were more vigorous than the best local varieties. However, the majority of them did not set good cobs. On the basis of these preliminary data 29 Indian and six foreign varieties, of which enough seeds were available, have been selected for detailed study and yield and maturity trials in the coming season.

Nearly 700 inbred lines have been started from both Indian and foreign varieties. Selfing of these inbred will be continued and only promising ones will be carried from year to year. It is necessary to build up a stock of promising inbreds of similar and diverse origins, of varying maturity and possessing different desirable characters for use not only in fundamental breeding problems but also for the production of suitable high yielding hybrids.

Eleven foreign 'double crosses' were also under observation. Their germination was very poor. None of these performed well in comparison to the open pollinated varieties.

To study comparative merits of selfing and sibbing 57 ear-to-row cultures of 13 indigenous and exotic varieties were selected and two selfs and sibs were attempted in each in such a way that each pair of a self and a sib had the male parent in common. Nearly 60 pairs of comparable selfed and sibbed lines have been started. These will be comparatively studied.

To determine the extent of homogygosity necessary before the inbreds are crossed for the production of hybrids, crosses between 1-year selfed lines and between 2-year selfed lines were made, 39 crosses between 1-year self and 12 crosses between 2-year self were obtained. These selfed lines have been further inbred and in the coming season crosses between 2-year self and 3-year self will be made.

Attempts to induce polyploidy in maize are being made.

Cytogenetics.

Autopolyploidy.—Autopolyploidy, as a method of crop improvement has been under investigation at this Division, for nearly ten years. By the applica-

tion of colchicine, polyploidy was induced in the following crops : chilli, sesame, gram, *Brassica campestris* var. *toria*, *B. campestris* var. yellow sarson, *B. nigra*, *B. juncea*, *B. tournefortii*, *Eruca sativa* and recently in linseed.

The autotetraploids obtained, showed a great range of variation as compared to their diploid progenitors and looked promising because of their gigas vegetative characters, increased seed size and seed weight. But they exhibited high sterility, both of pollen and seed, the degree of sterility varying from plant to plant, in all crops.

As for the causes of the sterility associated with the autotetraploids, Darlington (1937), Kostoff (1940) and many others attribute it to the high frequency of quadrivalents and the resultant meiotic irregularities. There are others who feel that the fertility of the autotetraploids is controlled by genetic factors. As a first step in increasing the fertility of tetraploids, selection of highly fertile single plants was resorted to. Side by side detailed cytological studies were also undertaken. The results obtained so far and the lines on which the work is being pursued now are discussed below under two separate heads, self fertilised crops and cross fertilised crops.

Self-fertilised crops.—Tetraploidy was induced in one good strain in each of the following crops :—chilli, gram and sesame. Cytological investigations were undertaken on the tetraploids of these crops. Though certain number of meiotic irregularities were met within pollen mother cells no aneuploid plants were recorded in the progeny, i.e., the tetraploids bred true to the chromosome number. Then the selection of fertile plants was resorted to, towards improving the fertility of the tetraploids. The results of selection over a number of generations are not very promising.

There are in the literature reports from other workers who obtained highly fertile tetraploids by selection alone in sesame, (Langham, 1942), buck-wheat, (Sacharov and others 1944) etc. So it was thought that different genotypes may react differently to this selection. In linseed, last year, tetraploidy was induced in varied materials. Some of tetraploids were highly fertile and they looked very promising. They had 5-6 seeds per capsule as against 8 seeds in the diploid. It is expected that selection here may be fruitful. The tetraploids of the different types have also been crossed *inter se*. Though there was a high frequency of quadrivalents observed in pollen mother cells, the disjunction of the chromosomes was resulting in normal balanced gametes.

In chilli tetraploidy was induced in four more types :—N.P. 21A, N.P. 34, N.P. 34 Bunch Mutant, and W.P.B. Intervarietal hybridization between the tetraploids was also attempted. During the year under report the breeding behaviour of two types, N.P. 51 and N.P. 34 Bunch Mutant with reference to chromosome number was investigated. In the progeny of one type, N.P. 34 Bunch Mutant, aneuploid plants were isolated while in the case of the other type no aneuploid plants were recovered. From a study of the meiosis in pollen mother cells, however, no significant difference was noted as regards the frequency of quadrivalents and that of laggards at other stages. It would therefore, appear that the genotype of the initial materials is an important factor.

In sesame tetraploidy was induced the F_1 hybrids obtained from inter-varietal diploid crosses. The study is in progress.

Cross-fertilised crops.

Brassica.—The results of selection have been different in *Brassica* species as compared to the other crops of the self-fertilised group. The fertility of the induced tetraploids of *B. campestris* var *toria* which was as low as 2 seeds per siliqua in the year 1941 has been now raised to an average of 13 seeds per siliqua, as against 15-20 seeds per siliqua in the diploids; frequently, tetraploid plants with 20 seeds per siliqua have also been identified. Such plants indicate the potentiality for further improvement. For the past few years, however, no appreciable increase in fertility was noticed in spite of rigorous selection.

It has been found that the tetraploids of *B. campestris* var. *toria* and *B. campestris* var. yellow *sarson* breed true for chromosome number, while those of *B. juncea* break down. So also the tetraploids of *E. sativa* do not breed true. The meiosis here is irregular and results in about 40 per cent of unbalanced gametes with chromosome numbers ranging from 18-24. Further, the free intercrossing of the tetraploids with the diploids and also the elimination of chromosomes during mitosis due to abnormalities in the spindle mechanism, contribute to the direct breakdown of the tetraploids in this species.

Interspecific hybridisation.

1. *Sesamum*.—For successful breeding, the breeder is dependent on the genetic variability in a crop which depends on the nature of the initial material. The breeder is therefore constantly searching for new and desirable genes, one of the main sources for such genes being the wild relatives of cultivated plants.

In sesame the possibility of utilising *S. prostratum*, a wild species, in breeding work with a view to evolving strains resistant to the phyllody disease and the pest, *Antigastra catanaulis*, was suggested, (Ramanujam, 1941). The hybrid more trisomics with the different extra chromosome of *S. prostratum* somes. By colchicine treatment a fairly fertile amphidiploid was obtained, (Ramanujam, 1942, 1944). As the amphidiploid was not suitable for direct cultivation, it was further back-crossed to the cultivated parent *S. orientale* and a triploid hybrid with 42 chromosomes was obtained. From the selfed progeny of this triploid hybrid, promising plants which were phenotypically like *S. orientale* with $2n=26$ chromosomes and showing evidence of genic exchanges between the two species have been selected. They look very vigorous and good.

In addition, a few plants with $2n=26+1$ chromosomes were identified in the progeny of the triploid hybrid and have been classified into three distinct derivative types. It is expected that by growing a large progeny of the triploid hybrid more trisomics with the different extra chromosome of *S. prostratum* will be isolated. These interspecific trisomics will be used for breeding improved strains of sesame.

2. *Wheat*.—With a view to investigate the complex genetic behaviour of ear and glume characters of certain plants from crosses between *T. vavilovo* and *T. vulgare* and between the former and *T. sphaerococcum*, a preliminary cytological investigation was undertaken in four off-types, B.C. Type 1, ear completely branched; B.H. types, ear half branched; E.G. type 1, extra glume; and E.G. type 2, extra glume. It was found that in some of these off-types there was a deletion of 1 to 4 chromosomes and in some other cases duplication of one chromosome, giving $6n-1=41$; $6n-4=38$ and $6n+1=43$ plants. A detailed cytological examination of these types is in progress.

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Crop Physiology.

(i) *Study of drought resistance in wheat.*—(a) Comparative study of 11 varieties of wheat under pot culture : The same experimental technique as reported last year was adopted (intermittent drought). The late varieties S. 40 and N.P. 735, were omitted and three other early varieties, viz. N.P. 745, N.P. 755 and N.P. 775, were included. The order in which these varieties stood as regards grain yield is indicated below :—

(decreasing towards right).

Normal watering—

Baluchis- tan.	CPH	Agra	N.P.	Punjab	C	N.P.	N.P.	N.P.	N.P.	N.P.
16	47	Local	755	9D	228	52	710	165	745	775

Intermittent drought—

N.P.	Baluchistan	CPH	C	NP	Agra	Punjab	NP	NP	NP	NP
52	16	47	228	755	Local	9D	165	710	745	775

N.P. 52 and CPH 47 performed well under drought like last year. The performance of N.P. 710, unlike last year, was poor under drought. In the normally watered series, N.P. 165 occupied a very low position in contrast with its first rank last season. The performance of the new inclusions, N.P. 745 and 755, was relatively poor both under control and intermittent drought. As compared to last season, tillering in all the varieties (common to both seasons), except N.P. 165 and N.P. 710, was much more profuse and consequently the yields were also much higher in the control series.

It was noticed in agreement with the last season's observation that under normal watering varieties with high tillering and earing capacity proved superior in yield and under drought varieties with inferior yields either tillered poorly or set fewer seeds per ear.

(b) Comparative study of 5 varieties in pot culture under intermittent drought upto ear emergence and after ear emergence respectively.

It may be noted that in the first case normal watering was renewed when anthesis occurred in 75 per cent of the mother shoots and in the second case drought was given six days after anthesis in 75 per cent of mother shoots. The varieties included in this study were : N.P. 710, N.P. 165, N.P. 52, Agra Local and C.228.

Drought up to ear emergence : On renewal of watering it was found that new tiller growth occurred profusely in all the varieties. Shooting, however, occurred later in N.P. 52, Agra Local and C. 228 as compared to N.P. 710 and N.P. 165 with the result that ear emergence and anthesis were delayed (in the first three) and grain size suffered due to supervening of atmospheric drought. Under normal watering N.P. 52, Agra Local and C. 228 continued to tiller for a longer time and thus gained in yield over the other two varieties. The difference in tiller number was, however, established under normal watering much earlier and thus earing and anthesis were not so much delayed as in the other case.

The difference between the effects of intermittent drought up to ear emergence and continuous intermittent drought may be accounted for in some such manner as follows. In both cases ears were already differentiated in the tillers which had grown out by 1/2/49. The further growth of the ears in all the tillers (inside the leaf sheaths) occurred under intermittent drought in one case and under normal soil moisture in the other. The number of spikelets was determined much earlier under identical conditions of drought in both the cases and thus did not differ. The growth and differentiation of the flowers, however, occurred under different conditions—under drought in one case and under adequate soil moisture in the other. In view of the fact that grain number per ear did not differ between varieties to the same extent under drought until ear emergence as in continuous drought differential flower production under restricted soil moisture is indicated. Soil moisture did not limit flower production under drought until ear emergence and thus the varietal factor regarding seed setting capacity was marked.

Drought after ear emergences : The late tillers in varieties with high tillering capacity, viz. N.P. 52, Agra Local and C. 228, failed to ear and dried up and these varieties again lost the advantage they usually have under normal watering. Thus the ear number as well as grain yield did not differ between varieties.

On comparing the effects of this drought with those of continuous intermittent drought, it was seen that tillers that 'shot' by the 1st of February primarily determined yield in the former and thus the number of flowers laid down in their developing ears was apparently not affected by drought, which in fact commenced later. This assumption is further supported by the number of spikelets per ear which was higher under drought after ear emergence. In continuous drought, on the other hand, all the shoots developed under drought and thus the varietal factor—tillering and seed setting—assumed importance.

(c) Moisture content of the ear : In another pot experiment moisture content of the ears of the plants under normal watering and drought respectively was compared and it was found that the moisture content of the ears under latter treatment showed practically the same variation as that under control. Evidently the ears maintained their moisture content at the expense of the moisture of other organs. There was no varietal difference in this respect and the differential seed setting among varieties, referred to above, is probably not influenced by the moisture factor.

(d) Comparative study of varieties under field conditions : Randomized field experiments under irrigation and 'barani' were laid down at Delhi, Karnal and Pusa. Each variety was replicated six times and the net plot size was 13 ft. $\times$ 10 ft. Twenty clumps from each replicate were sampled at harvest and observations on grain weight, ear number, spikelet number and

grain number were recorded. Conclusions based on these observations are summarised below :

Delhi : The varieties stood in the order indicated below :—

C	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
228	710	775	4	165	52	755	745

(Under irrigation)

C	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
228	710	165	4	52	755	775	745

(Under barani)

It is evident that the order of varieties as regards yield has changed under field conditions. N.P. 52, whose performance was so superior under drought in pot culture does not any longer maintain the premier position. N.P. 165, on other hand, has shown better performance under *barani* than under drought in pot culture. C. 228, no doubt, has proved superior under both the conditions. N.P. 775 and N.P. 745 gave low yields both under *barani* and under drought in pot culture.

Ear number alone appeared to be correlated with yield under irrigation whereas under *barani* grain number per ear and 1000 grain weight were correlated with yield.

The overall reduction in yield under *barani* was to the extent of about 25 per cent and could be largely accounted for by reduction in ear number.

Karnal : The varieties stood in the order indicated below :—

Punjab	N.P.	N.P.	N.P.	N.P.	N.P.	Agra	N.P.	N.P.
9D	775	4	165	775	745	Local	710	52

(Under irrigation)

Punjab	N.P.	Agra	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.
9D	755	Local	775	710	165	4	52	745

(Under barani)

Only under *barani* did Punjab 9D prove superior to other varieties except N.P. 755 and this superiority was mainly due to higher ear number. The overall reduction in yield under *barani* was to the extent of about 43 per cent and was largely accounted for by reduction in ear number and to some extent by reduction in grain number per ear.

Pusa : The varieties stood in the order indicated below :—

N.P.	N.P.	N.P.	N.P.	N.P.	N.P.	N.P.	Agra	C	Punjab
755	775	745	710	52	165	4	Local	228	9D (Low moisture)

N.P.	N.P.	N.P.	N.P.	N.P.	C	N.P.	N.P.	Agra	Punjab
775	710	52	745	755	228	4	165	Local	9D (high moisture).

It may be noted that C. 228, and Agra Local and Punjab 9D, which performed so well at Delhi and Karnal respectively yielded very poorly at Pusa and that yield was correlated with grain number per ear and 1000-grain weight.

Although the order of varieties as regards yield differs with site and experimental technique (i.e. pot and field culture) the indication about the yield being determined by tillering or seed setting capacity under restricted soil moisture is clear. It was seen from the pot experiment how the effect of these two factors on yield was modified according to the stage at which soil moisture became limiting. Under *barani* the crop is growing under a gradually diminishing soil moisture status and the time by which its effect is exerted would depend upon the amount of moisture stored during the preceding rainy season and also upon the amount of winter rainfall. Again tillering capacity would also be modified by other environmental factors, particularly temperature (also nitrogen status).

(e) Response of plants from seeds developed under drought : It has been claimed by some Russian investigators that the plants raised from seeds that have developed under arid conditions usually acquire drought resistance. The seeds obtained last season from the normally watered and the drought series were sown separately and the plants were again raised under normal watering and intermittent drought. There was no difference in the yields of plants raised from the seeds from the two different sources.

(f) Pre-treated seed : Pre-treated seeds (alternate soaking and drying) of variety N.P. 4 were sown along with ordinary seeds in a replicated field experiment at Sawai Madhopur under 'barani'; no difference in germination was observed and the crop subsequently failed completely due to absence of rain during winter and very low rainfall during the preceding monsoon.

(ii) *Physiological analysis of factors concerned with yield.*—It was observed last season that the photosynthetic activity of the ear differed with varieties. A detailed analysis of the relation between the increase in total dry matter of the plant (main shoot only), after anthesis, and grain formation in the case of 6 varieties, viz. N.P. 52, N.P. 710, N.P. 165, Punjab 9D, Agra Local and CPH 47 as undertaken during the season under report.

The increase in plant weight after anthesis was significantly the highest in N.P. 52. It was more or less identical with the grain weight in the case of all the 6 varieties indicating thereby that grains were very largely filled at the expense of the dry matter derived from the net assimilation during the post-anthesis period.

The percentage contribution by photosynthesis in the ear to total net assimilation was the highest in N.P. 710 although it was significantly greater than that in N.P. 165 and CPH 47 only. The percentage contribution by photosynthesis in the leaf was the highest in CPH 47, although it was significantly greater than in Punjab 9D and N.P. 710 only. The contribution by photosynthesis in the stem did not differ significantly with the varieties.

The percentage contribution by photosynthesis in the leaf, ear and stem to net assimilation corresponded more or less with similar contribution to grain weight.

In another experiment the effects of defoliation, puncturing the stem (12 punctures with a needle on the internode bearing the ear), and a combination of the last two on the grain yield of 5 varieties viz, N.P. 165, N.P. 52, Punjab 9D, N.P. 710 and Agra Local, were compared. By puncturing the stem the transport of the assimilate from the leaves and the stem is checked and it may be expected that a variety whose ear made a proportionately greater contribution to grain filling would suffer relatively less in yield. In view of the observations on assimilation noted above, N.P. 165 may be expected to suffer the most in yield due to puncturing whereas the other varieties would suffer more or less to the same extent. Actually as a result of puncturing N.P. 52 and N.P. 710 suffered the least, Punjab 9D and Agra Local suffered a little more and N.P. 165 the most.

It is tentatively concluded that under normal conditions varietal differences as regards grain number and grain size, the two characters which have an important influence on yield, are not determined by net assimilation during post-ear emergence period but under conditions which restrict or prevent photosynthesis, these characters may be affected according to the relative contribution made by photosynthesis in the different organs to net assimilation; as such the possibility is indicated of interpreting along these lines the differential response of varieties to at least some adverse environmental conditions.

(iii) *Study of the influence of light and temperature on growth and development.*—(a) The effect of sowing time on development in wheat: The main object of this study was to see how the time of sowing influenced the differential stages of the reproductive phase in wheat. The reproductive phase was considered to have begun when the vegetative growing point elongated and double ridges formed (rudiments of spikelets). The completion of the pre-fertilisation phase was judged at the point when the anthers in the ear dehisced. Four sowing dates viz, September 21, November 11, December 8 and January 11 and two varieties N.P. 165 (early) and *T. vavilovi* (late) were included in the study which was carried out under pot cultures.

Under the conditions of this experiment the time taken for the initiation of the reproductive phase was not much affected by day length and temperature differences under the different sowing dates. During the subsequent stage the growth of the stem was markedly influenced by both temperature and day length and as a result ears emerged much earlier in plants sown on 21/9 and 11/1 respectively.

Seeds collected from plants sown in September were also used in the experiment of sowing date 11/1 and the plants from these seeds and those from seeds collected from the harvest of the previous season were equal in vigour and yield. It is not necessary to wait for the seeds to ripen normally on the plants sown in September. Quite viable (though not plump) seeds can be collected from ears cut off about a fortnight after dehiscence and drying them gradually by keeping their stalks dipping in water. The possibility of raising three generations of wheat in a year by suitable modification in day length and thus hastening breeding programme is indicated.

Observation on *T. vavilovi* indicated no difference, due to sowing time, in time interval between sowing and appearance of double ridges, it being about 132 days. From double ridges to anthesis the time varied as 69, 39 and 29 days respectively for the sowing dates 18/9, 6/11 and 8/12. Microdissection of the plants sown on 18/9 showed in November an elongation of the growing point indicating a transition towards the reproductive phase. During November tillering also continued at a very slow rate. During December, however,

the rate of tiller production increased conspicuously and the growing point appeared dome-shaped (vegetative). Day length was fast decreasing then and apparently reversion to vegetative stage took place as a result thereof. During 1948 this hypothesis was, therefore, tested by exposing some of the September sown plants to a long photoperiod from the first week of November. Double ridges on the growing point were observed in the middle of December, about 100 days after sowing, and anthesis occurred 35 days later during the last week of January. Grain setting as well as grain size was good in these plants whereas it was very poor in all the other cases as anthesis occurred during April and May and the grains ripened during hot and dry weather. It would appear that low temperature treatment during germination is not absolutely necessary for inducing early and timely flowering in this variety.

(b) The effect of sowing time on growth and yield of wheat : An experiment was undertaken to study the effect of length of day and sowing time on growth and yield in two varieties of wheat grown under pot culture. The treatments included three sowing dates viz. 15th November, 6th December and 27th December, 1948, long and normal photoperiod, and varieties N.P. 165 and N.P. 771. Continuous artificial illumination was given throughout the night.

The long day hastened emergence of ear in both the varieties in all the three sowings ; it was earlier by about three weeks in the first sowing and by about a fortnight in the other two.

The spikelet number per ear and 1000-grain weight were reduced under the long day and thus the grain yield, as compared to the normal day, suffered. It may be noted in this connection that the normal day length does not vary appreciably during the first 8 weeks after sowing under all the 3 sowings. The range in hrs. and mins. varies as 10, 38—10, 24 in the first sowing, 10, 18—10, 38 in the second sowing and 10, 14—11, 38 in the third sowing.

Tillering progressed at a slower rate under the long day, but later when these plants were transferred to normal day (soon after ear emergence in main shoots) a second cycle of tillering commenced and ultimately they had a much greater number of tillers than the normal day plants. Ear emergence in these tillers was, however, very much delayed and, therefore, the grain size was reduced.

In the normal day series, maximum tiller number was attained in all the three sowings in approximately the same length of time (about 8 weeks). Delay in sowing slightly reduced the maximum tiller number but its adverse effects on ear number was much greater. Ears emerged earlier approximately by three days in the second sowing and by about a week in the third (from the time of planting). It is thus apparent that the rate of vegetative growth (tillering) and development did not differ considerably under these sowings. The tillers appearing towards the end of the tillering phase in the late sowings had much less chance of survival and development apparently due to rapidly increasing temperature and diminishing relative humidity. It is, therefore, worth considering whether a variety with a more rapid tillering rate would not suit delayed sowing better.

(iv) *Physiological aspects of plant nutrition.*—(a) A study of the growth and uptake of nitrogen in wheat N.P. 165 under normal and short day.

The object of this study was to see how the rate of uptake of nitrogen was related to different growth stages of the plant. A variant in the time of initiation of the reproductive phase was introduced by means of short day

treatment (less by 3 hours than the normal day). The water culture method was adopted with a view to ensuring proper sampling of the root system. The culture solution was changed once a week. As compared to normal day the maximum growth attained under short day was less and the rate of growth was slower in the early stages; formation of double ridges was delayed only by 4 days but anthers in the form of solid transparent structures were first recognised after about 8 weeks in normal day plants and after about 9 weeks in short day plants. The peak rate of absorption of nitrogen coincided approximately with the initiation of the floral structures under both treatments. The concentration of sugars in the roots bore no relation to the decline in the rate of uptake after this peak. The curve of rate of uptake of nitrogen showed a second peak which appeared to be related to the continued production of tillers after ear emergence.

(b) A study of the growth and uptake of nitrogen in three varieties of wheat: Three varieties viz. N.P. 165, N.P. 52 and N.P. 710 and two levels of nitrogen (no nitrogen and nitrogen) were included in this study under pot culture. Nitrogen was added as ammonium sulphate at the rate of 3 gm. per pot. One gm. superphosphate (15 per cent. P_2O_5) and one gm. potassium sulphate per pot were common to both treatments. There were 6 plants per pot and 30 pots in each treatment. 5 pots under each treatment were sampled 36, 57, 78, 118 and 141 days, respectively, after sowing for determination of dry matter and nitrogen content.

The varietal difference in grain yield and ear number, at both levels of nitrogen, was statistically not significant. On the whole, N.P. 165 had a significantly lower grain number as well as maximum tiller number at both levels of nitrogen.

The smaller grain number in N.P. 165 and N.P. 710 was compensated by the larger grain weight and thus yield difference between varieties disappeared. Although estimation of the nitrogen content of replicate sample was not made, judging from the much larger order of difference between the nitrogen content of N.P. 52 on one hand and that of N.P. 165 & N.P. 710 on the other, as compared to that of other characters like grain yield and ear number it is tentatively concluded that N.P. 52 absorbed more nitrogen than N.P. 165 or N.P. 710. Inspection of the curves of uptake of nitrogen indicated that the rates of uptake of nitrogen by the three varieties were more or less similar up to 78 days but between 78 and 113 days it was much higher in the case of N.P. 52 and this largely accounted for the ultimate higher nitrogen content of this variety. Active tillering phase was already over by 78 days. The only other difference between the varieties consisted in the larger number of spikelets and grains in N.P. 52. There was significantly greater number of points located in the N.P. 52 ear for protein synthesis (in the grains) and thus apparently more nitrogen was absorbed. The generally higher percentage nitrogen content of the grain of N.P. 52 may also be noted in this connection. It would appear that in so far as grain yield is concerned N.P. 165 and N.P. 710 utilised nitrogen more efficiently than N.P. 52.

Nitrogen had a consistently favourable effect upon yield and all other characters and the interaction between variety and nitrogen was not statistically significant indicating that all varieties responded equally well to nitrogen.

(v) *Plant Hormones*.—(a) *Hormonal weedicides*: A replicated field experiment was undertaken to compare the effect of spraying with 'methoxone' with that of hand weeding on the yield of wheat N.P. 165. The treatments

included (1) spraying once with 'methoxone' at the rate of one lb. per acre about 7 weeks after sowing, (2) spraying twice, the other dose being repeated after about three weeks, (3) hand-weeding twice, corresponding with the time of spraying and (4) unweeded control.

The mean yield in mds. per acre (single plot size 1148 acre) in the different treatments is shown below :

Twice weeding	Spraying once	Spraying Twice	Control
17.22	15.64	14.42	13.2

It will be seen that one time spraying was as effective as weeding twice and significantly improved yield over the unweeded control. There was some indication that spraying twice depressed the yield at least as compared to weeding. Similar effects of higher doses have been reported in the literature.

The weeds were collected after they were removed from the treatment plots, dried under the sun and weighed. The dry matter (from 2 weedings) worked out as about 150 lbs. per acre with a total nitrogen content of 5.6 lb.

(b) Effects of 2, 4-D on growth and development : The effect of small concentrations of 2, 4-D, in the culture medium, on the growth and development of an early (N.P. 165) and a late (S. 40) variety of wheat was investigated. The plants were raised in water as well as soil (pot) culture. In the water culture the strength of 2, 4-D was maintained, at $1\frac{1}{4}$ ppm, whereas it was added to the plots in two doses, viz. 1.6 mg. per pot in the beginning and 0.8 mg. later. In view of the longer growth period of S. 40 one more dose of 0.8 mg. was added in this case. As the field capacity of the soil was about 15 per cent. the aqueous concentration in the soil worked out as about 1 ppm. In view of the gradual decomposition of the substance in the soil its effective concentration would, however, be much below 1 ppm.

The root system was the first to show the adverse effect of 2, 4-D in the water culture. The irregular features were failure of the leaves to unfold fully (in the later stage), twists in the ear heads and occasionally branching in the immature ears. All these features were much more pronounced in water culture ; S. 40 was, however, free from these irregular features in growth, although its root growth was affected to the same extent as in N.P. 165. The uptake of nitrogen was not reduced to the same extent as the total dry matter. Water content of the tissues was also reduced. The time of ear emergence and dehiscence was delayed by about a week in N.P. 165 only.

In the pot culture yield was reduced in N.P. 165 mainly due to reduction in tillering and ear number. In S. 40 the grain yield was reduced, though not significantly, mainly due to reduction in grain number per ear. In the water culture N.P. 165 also suffered in yield mainly due to tillering and ear number. In S. 40 the plants dried up, before grains were set, due to root rot.

Plant Introduction and Exploration.

Pending the institution of a fully organised Bureau of Plant Introduction and Exploration, the Indian Council of Agricultural Research sanctioned a nucleus scheme which started functioning from April 1946. Since then collection and study of the material imported from various countries and also from within the country have been continued. The following is a summarised account of the progress of work on various plant groups during the year under report.

Subsidiary food crops.—In view of the increasing importance of subsidiary food crops to combat the present food shortage in the country urgent attention was given to the introduction, trial and selection of foreign varieties which may be high yielding and of better quality as compared to the indigenous material. Work was in progress on sweet potato, tapioca, yams, and edible canna.

Sweet potato.—In India till recently no attempts appear to have been made to try improved foreign varieties of sweet potato for the obvious reason that this crop has not been ranked amongst the commercial crops of this country though its cultivation covers a sufficiently wide range. For the improvement of this crop a beginning was made with a set of eight American varieties, obtained through Mr. Boshi Sen of Almora, three varieties from Taiwan (Formosa) and the local variety. In the July planting the Taiwan Native variety "Tie-Shin Tun" showed the best performance. The American varieties B. 219, B. 4306, F.B. 4004 and Pelican Processor were also promising as short duration high yielding varieties. A second planting was made in January and harvested in mid-June, the variety B. 219 was found to be the best. This showed that this variety may be useful for raising an additional crop in the fields cleared of sugarcane, cotton and early winter vegetables, etc. Meanwhile about half a dozen varieties from South Africa and two dozen Indian varieties were added to the collection. In the new trials that have been taken up about 45 varieties have been included. Periodical plantings have been taken up to find the climatic requirements of various varieties. Selected varieties which did well in the first trial have been planted at the Substations at Karnal (East Punjab), Pusa (Bihar) and Coimbatore (S.I.) Planting material is being multiplied for trials in the provinces and state unions to select suitable varieties for varying climatic conditions.

Tapioca.—As a source of food, tapioca (*Manihot utilissima*) is reported to be comparable with the sweet potato. This tuber crop is at present cultivated on a commercial scale in Travancore, Cochin and Malabar and in parts of Madras. Preliminary work was undertaken to examine the possibilities of introducing suitable varieties into the regions where it is not at present cultivated. A start was made with three varieties from Travancore. The general growth of the plants at New Delhi was good and one of the varieties, 'Ariyan', formed good tubers which indicates that with further experimentation it may be possible to extend its cultivation in the North West. Frost is one of the limiting factors in its cultivation in this region but it was observed that as the plants become shrubby before the frost period they are not usually damaged by the ground frost which is the more common type. For further trials ten more varieties have been obtained from Travancore. Arrangements have been made for trials in different parts of the country and the Ministry of Agriculture is arranging for the supply of cuttings from Travancore.

The tuberous rhizomes of the edible canna (*Canna edulis*), also called "Queensland Arrowroot", are considered to be one of the best starchy foods. The crop is said to yield about 15 tons of fresh tubers per acre. A satisfactory crop was raised at Delhi during July-January. The tubers on analysis were found to compare favourably with wheat and sweet potato as regards carbohydrate content but were inferior in protein and fat contents.

Yams (*Dioscorea esculenta* (sutni) and *D. alata* (phar) produce starchy tubers similar to the potato in food value and taste. Yams are more commonly cultivated in the eastern provinces of Bihar, Bengal and Assam where they form an important article of diet of the poorer population. Preliminary trials

were undertaken with the varieties obtained from Bihar. The crop is coming up very well and there are indications that it may be successfully introduced into this region.

Other Food plants.

Beans.—In India beans are practically unknown as field crops for the production of dry edible beans, large quantities of which are annually imported into this country. The two important commercial beans are the kidney bean (*Phaseolus vulgaris*) and lima beans (*P. lunatus* and *P. limensis*). Several varieties of the beans were introduced from U.S.A., Burma and Philippines. An American variety of bush lima bean, "Fordhook", appears to merit further attention. In order to find out the most appropriate sowing time for this bean periodical plantings were made. Better germination and growth were observed when the sowing was made at the break of the monsoons than when sown during the dry part of summer. This bean is being multiplied for the trials. A variety of cowpea (*Vigna sinensis*) from Philippines was observed to be very early beginning to bear in 35-40 days after sowing. It is considered useful as a vegetable. The seeds are being multiplied.

Cruciferous vegetables.—Chinese Cabbage (*Brassica pekinensis* and *B. chinensis*) which is not really a member of the cabbage group is a popular vegetable of China. A variety of *Brassica pekinensis* known as "Chihli", from Philadelphia was found promising as a high-yielding good quality leafy vegetable. It was observed that even if the plants did not give compact heads the tender leaves could be plucked at intervals, and cooked like spinach and other pot-herbs or used as salad. Difficulty was experienced in producing good seed in sufficient quantities under the conditions prevailing at Delhi. Exposure to long day conditions, however, helped the plants to come in flower early and also to set good seed. *Brassica chinensis* was not found as useful as *B. pekinensis* on account of its relatively poor quality. A collection of varieties of radish from China, which is claimed by some to be the original home of radish, was studied in some detail and some varieties definitely superior to our local varieties were selected for further trial.

Sunflower.—Sunflower at present is not one of the important oil-seeds of India. Three varieties from Australia and four from South Africa were tried at Delhi and Pusa, the Australian varieties were tried also at Coimbatore during the *rabi* season. One of the Australian varieties, which is perhaps an F_1 hybrid, formed large compact heads and bold seeds. The South African varieties were generally late and tall-growing whereas the Australian material was early and dwarf-growing.

Grasses and legumes.—Extensive breeding work has been in progress in some of the foreign countries specially in the U.S.A., U.K., Australia and New Zealand on the improvement of forage plants. A number of improved strains of important forage plants have thus been evolved. It has been possible to build up a useful collection of annual and perennial forage plants by exchange and mutual cooperation. The work on the agronomic aspects of grasses and legumes is mostly undertaken by the Division of Agronomy who also carry out detailed studies and the chemical analyses. Certain aspects of the botanical investigations particularly those relating to the study of seed production for purposes of seed multiplication have, however, been in progress. The materials appearing agronomically important, particularly those observed to maintain perennial nature, are also noted. Among the recent introductions

of grasses Giant Panicum (*Panicum antidotale*), Dallis grass (*Paspalum dilatatum*), and Bunch Grass (*Pennisetum ciliare*) are considered useful as perennials. Dallis grass was conspicuously green throughout the winter when most other grasses were drying. The Brome grasses (particularly *B. unioloides*) and canary grasses (Reed canary grass, *Phalaris canariensis*) were two promising annual winter grasses which also set abundant seed.

Legumes.—The collection of clover, medicks, melilots, vetchs, lupines, *Stylosanthes* and *Lotus* etc. was under study.

Grasses and legumes for soil conservation.—Neither the tropical kudzu (*Pueraria phaseoloides*) nor the kudzu vine (*P. hirsuta*) flowered in the second year. The Himalayan variety of *Lespedeza cuneata* was observed to differ from the American variety in having a tall non-bushy habit. Out of the three Love grasses which are well known for soil conservation viz., Weeping, Lehman and Boer Love grasses, the last one was found to be inferior to the other two. The love grasses except one of the varieties of weeping love grass (*E. curvula* var. *valida*) were poor in flowering and seeding. All these, however, formed well developed clumps with strong root system desirable for soil conservation purposes.

The grasses and legumes introduced were supplied to the Agrostology Section of the Agronomy Division for maintenance, further study and trial.

Plant Exploration and collection of wild relatives of crop plants.—It has been possible to build up collections of indigenous wild species of *Solanum* (related to brinjal), *Hibiscus* (related to Okra), *Phaseolus* (related to the common pulses), *crotalaria* (related to sunnhemp) and others. The collections of *Solanum* and *Hibiscus* were under detailed investigation as possible breeding materials.

BOTANICAL SUBSTATION, PUSA.

The substation at Pusa in Bihar Province, which is attached to the Botany Division, is entrusted, amongst other functions, with the maintenance of certain collections of N.P. (New Pusa) types evolved at this Division and the multiplication of the more important types for distribution to provinces and states. It also serves as a useful station for a distinct climatic and soil zone of the country for testing the recently-evolved or newly introduced commercial strains of crop plants. Some of the experimental material of the main Division is grown there for observations and a few long range projects like the manurial and rotation experiments are being worked out at the substation in collaboration with Chemistry and other Divisions.

During the year under report 12 wheat strains of hybrid origin recently evolved at the Division were under yield trial along with N.P. 52. The following table shows the yields in lb. per acre (calculated) obtained from some of these strains during 1947-48 and 1948-49.

Variety	1947-48	1948-49
N.P. 762	695.4	844.2
N.P. 764	719.4	790.6
N.P. 52 (control)	683.4	777.2

In oats a varietal trial was repeated with 3 N.P. varieties and 13 recently-evolved hybrids and two of the new hybrids gave the highest yields. In a yield trial in lentil four newly-evolved hybrids were tried against three N.P. types. N.P. 32 out yielded all others while a new hybrid did quite as well.

The progeny of the wilt-resistant crosses in rahar (*Cajanus cajan*) which is under tests at the main Division was studied with regard to wilt incidence and a few cultures possessing early maturity, high yield and wilt resistance have now been isolated. The autotetraploid population of chilli has been under observation for a number of years with a view to selecting lines of high fertility but it has not yet been possible to achieve any substantial improvement in fertility in the population as a whole although a few plants with high fertility are met with every year. These findings endorse the observations made at the main Division. The new manurial and the permanent manurial and rotation experiments were continued according to schedule. Full reference to these will be found in the reports of the Divisions of Agronomy and Chemistry.

The collections of N.P. types and other exotic cultures in cereals, pulses, oilseed and fibre crops and tobacco were maintained as in the previous years and the types under distribution were multiplied.

PROGRAMME OF WORK (1949-50).

I. Applied Genetics.

1. Studies in the improvement of Indian wheats.
2. The work reported on breeding crop plants for disease resistance and other qualities will be continued particularly in wheat, linseed and pigeon-pea.
3. Trials with newly-evolved strains of different crop plants like wheat, linseed, tomatoes etc. in provinces and states.
4. Investigations on utilization of hybrid vigour for improvement of maize in India.

II. Cytogenetics.

1. Cytogenetical studies of induced autotetraploids in crop plants like *Brassica*, *Eruca*, *Sesamum*, *Capsicum* and *Cicer* with special reference to breeding and economic importance.
2. The progenies of the newly induced autotetraploid and interspecific hybrids in *Linum* will be examined. Study of heterostyly with reference to compatibility in *Linum*.
3. Cytogenetical studies in the interspecific crosses in *Sesamum*.
4. Cytogenetical investigations of the interspecific hybrids in *Triticum* with special reference to ear and glume characters. Attempts will be made to effect other intergeneric and interspecific crosses.
5. Cytogenetical studies in some of the non-tuberiferous species of *Solanum*.
6. Investigations on the application of cytological techniques with reference to chromosome structure will be made.

III. Crop Physiology.

1. Studies on drought resistance in wheat will be continued both under pot and field culture.
2. Physiological analysis of factors concerned with yield will be further extended.
3. Investigations on the influence of light and temperature will be further extended.

4. Uses of hormonal weedicides will be further explored.
5. Studies on the physiological aspects of plant nutrition will be extended.

IV. Plant Introduction.

1. Further material will be imported from various countries and studied under various climatic conditions as far as possible.
2. Arrangements will be made for the trials in the provinces and states unions of the plants of which enough seed has been multiplied. Special attention will be given to the study of sweet potato and tapioca, beans, etc.
3. Requests for seeds of miscellaneous plants from the provincial workers will be complied with.

REPORT OF THE SUGARCANE BREEDING STATION, COIMBATORE

Sugarcane Breeding

(a) *Hybridization and Selection.*

The programmed crosses were successfully effected excepting a few experimental crosses which could not be done due either to the non-flowering of varieties like Co. 620 and Co. 622 or due to paucity of arrows as in Co. 475, Co. 615 and Co. 649. In all 105 crosses were done for obtaining economic seedlings and about 200 crosses and selfs for genetical studies.

(1) *Bulk and Semi-bulk scale crosses.*—In addition to the four pistil parents Co. 508, Co. 527, Co. 534 and POJ. 2878 which have figured prominently in the breeding programme during the last three years, one more variety was utilised for raising seedlings on a bulk scale. It is Co. 270 which was crossed with Co. 301. Further extensive use in crossing work, of Co. 475, Co. 638 and Co. 644 was warranted by the experience gained last year and these were employed this season on a Semi-bulk scale. The following is a list of the more important crosses effected during the year (i) Co. 270 $\times$ Co. 301, (ii) Co. 508 $\times$ Co. 617, (iii) Co. 508 $\times$ Co. 453, (iv) Co. 527 $\times$ Co. 617, (v) Co. 534 $\times$ Co. 285, (vi) Co. 534 $\times$ Co. 453, (vii) POJ. 2878 $\times$ 617, (viii) Co. 313 $\times$ Co. 638, (ix) P. 4626 $\times$ Co. 644, (x) Co. 421 $\times$ Co. 617, and (xi) Co. 475 $\times$ S.G. 63|32.

(2) *Experimental crosses for evaluation of parents.*—Six Co. varieties were used in experimental crosses to get an idea of the seedlings obtained from them. These are Co. 467, Co. 615, Co. 649, Co. 677, Co. 683, and Co. 685. Of these, Co. 467 and Co. 615 are fairly high yielding varieties with good sucrose content and are doing well in tropical Testing Stations. Co. 649 is a vigorous variety though with moderate sucrose content. Co. 677, Co. 683 and Co. 685 are three of the recent releases which are promising.

(3) *Sorghum crosses.*—Two sweet Sorghums were utilised on Co. 349 and POJ. 2725. Four tetraploid sweet Sorghums have now been obtained from U.S.A. and these will be resown in time for utilising next flowering season for crossing.

(4) *Fodder crosses.*—This item of work is now a minor one and of the nature of a subsidiary line. Seedlings of the Napier grass (*Pennisetum purpureum*, Schum.) mentioned in the last report were studied. They were found to resemble Napier grass in morphological characters and the chromosome numbers were found to be the same as that of Napier grass, viz., $2n=28$. These crosses were again tried, care being taken this time to emasculate before dusting pollen of sugarcane. No seed setting took place. In another set of crosses the flowers of *S. spontaneum* (Coimbatore) were emasculated and the pollen of Napier grass dusted. There was no seed setting in these crosses also.

(5) *Nursery seedlings*.—The germination in the seed pans was satisfactory. Earthenware seed pans continue to be used, but these will be substituted by glazed pans. Very good germinations have been recorded in the following crosses :—(i) Co. 421 $\times$ Co. 617, (ii) Co. 523 $\times$ Co. 527, (iii) Co. 534 $\times$ Co. 449 and (iv) POJ. 2878 $\times$ Co. 453.

From out of a total of 18,000 seedlings in the 2nd ground nursery, 413 were selected for trial in the preliminary plot. The following combinations gave desired type of economic seedlings : (i) Co. 349 $\times$ Co. 557, (ii) Co. 508 $\times$ Co. 617, (iii) Co. 527 $\times$ Co. 453, (iv) Co. 313 $\times$ Co. 617, (v) Co. 508 $\times$ Co. 638, (vi) Co. 467 $\times$ Co. 658, (vii) POJ. 2878 $\times$ Co. 617, (viii) Co. 475 $\times$ SG. 63|32 and (ij) P. 4626 $\times$ Co. 449. The first mentioned cross gave seedlings with good vigour, habit and brix. The canes were on the thickish side. Seedlings of Co. 508 $\times$ Co. 617 were very good from growth, tillering and sucrose points of view, but the canes were on the thinner side. Seedlings of Co. 527 $\times$ Co. 453 were good in growth and tillering, but had only average brix. So also was the case with the seedlings of Co. 534 $\times$ Co. 453 cross. The three crosses, viz., Co. 313 $\times$ Co. 617, Co. 508 $\times$ Co. 638 and POJ. 2878 $\times$ Co. 617 yielded seedlings of good sucrose content and fair tillering. It is proposed to repeat these three on a bulk scale next season.

(6) *Test plots*.—From the preliminary plot of 1948-49 season 164 varieties were selected for trial in the final plot. A good number of desirable seedlings were obtained from the cross Co. 508 $\times$ Co. 301, the seedlings being good in sucrose and tillering. The other crosses which gave the desired economic types are (1) Co. 508 $\times$ Co. 313, (ii) Co. 508 $\times$ Co. 453, (iii) POJ. 2878 $\times$ Co. 371, (iv) Co. 443 $\times$ Co. 453, (v) Co. 603 $\times$ S.G. 63|32 and (vi) P. 4626 $\times$ Co. 644.

In the last year's final Test Plot 228 seedlings were under trial. Out of these 56 were raised to the status of Co. canes.

(7) *Bamboo crosses*.—It was thought desirable to repeat this cross as none of the seedlings from the previous crosses have been promising. The crosses have now been repeated using four separate sugarcane varieties and one protogynous form of *S. spontaneum* as female parents on all of which the pollen of *Bambusa arundinacea*. Wild which had been previously tested for viability was dusted. For securing the desired flowering in *Bambusa*, the technique previously used at the Station was employed and satisfactory flowering was obtained. An additional precaution taken this time was to test the viability of *Bambusa* pollen before utilising it for crossing. The pollen was found to germinate satisfactorily in a 14 to 16 per cent. sugar agar culture medium (commercial sugar 14 to 16 per cent. + 0.7 per cent. agar agar). The germination of *Bambusa* pollen in vitro was about 60 per cent. and the average length of the pollen tube in culture was about 800 microns which is fairly satisfactory.

The sugarcane varieties employed as female parents were Co. 421, POJ. 2725, POJ. 213 and Black Cheribon and the protogynous form of *S. spontaneum* employed was the Uganda form G. 3011. No germinations were obtained in the controlled crosses (1) POJ. 213 $\times$ *Bambusa*, (2) Black Cheribon $\times$ *Bambusa* (3) *S. spontaneum* $\times$ *Bambusa* and in the selfs of the female parents. In the cross Co. 421 $\times$ *Bambusa* 20 seedlings have been obtained, while in the cross POJ. 2725 $\times$ *Bambusa* only one seedling was obtained which later died. These Co. 421 $\times$ *Bambusa* Seedlings are being

grown for detailed observations including cytological examination. It may be mentioned, however, that at this stage (3 months old) the seedlings look very much like other sugarcane seedlings of Co. 421.

(8) *Crosses for evolving chewing types*.—The following two crosses were effected for obtaining soft rinded chewing seedlings : (i) Co. 603 $\times$ E.K. 28 and (ii) B. 6308 $\times$ Co. 290.

OTHER INVESTIGATIONS.

(A) Botanical Studies.

(1) *Occurrence of starch as a specific character in Saccharum*.—Studies on the occurrence and amount of starch in the stem of sugarcane varieties have given an indication that the presence or otherwise of starch is a definite specific character for certain species of *Saccharum*. The amount of starch in the stem was qualitatively determined by treating the sections with iodine solution. It has been found that there is practically no starch in *S. officinarum* varieties while there are relatively large quantities in *S. Barberi*. Traces to small quantities of starch were noticed in *S. spontaneum* while *S. sinense* came in between *S. Barberi* and *S. spontaneum*. There was no starch accumulation in *Sclerostachya* and *Narenga*. Fair to large quantities of starch accumulation were noticed in eight types of *Erianthus*. For these studies observations were made on 78 varieties of *S. officinarum*, 26 varieties of *S. spontaneum*, 85 varieties of *S. Barberi* and 25 varieties of *S. sinense*.

The above studies are proposed to be extended to the hybrid seedlings at the Station to ascertain if the occurrence or otherwise of starch could be used for determining the genuine hybrid nature of a seedling.

(2) *Cell size and starch content of leaf as index of early maturity*.—Preliminary studies on 8 early and 8 late varieties have shown that early maturing varieties have smaller cells in their leaves. The size of stomata, plastids, bulliform cells, etc., are smaller in the early varieties as compared to those of the late ones. The early maturing varieties like Katha, Co. 508, Co. 557, Co. 281 etc., have accumulations of starch in the plastids early in the morning even before the leaves start the photosynthetic activity while in the leaves of late maturing varieties no starch accumulations are noticed.

(B) Chemical Studies :

(1) *Effect of soil conditions on growth and quality of cane varieties*.—It has been observed that the growth of cane varieties as also the chemical composition of the juice in the garden land plots have been found to be different from those of the wet land plots, though they may be almost adjacent to each other. Our preliminary study showed clearly (1) that not only the individual canes were heavier in the garden land but also the number of canes per row was generally more, thus contributing to a greater tonnage (2) regarding juice quality, the canes in the wet lands were in all cases and throughout the crushing season superior to those in the garden lands and maturity was attained earlier in the wet land.

The experiment was repeated this year with three varieties viz., Co. 312, Co. 421 and Co. 419 with four replications to find out the differences in growth, tillering, yield and quality of the varieties. The percentage of flowering was also recorded. The representative profiles, one in the garden land and another in the wet land were dug and samples drawn from every distinct horizon or

from every foot as the case may be. The analysis of these samples is still under progress. A clamp in each row of every replication of each variety was cut in the month of December, January, February and March, the total number of millable canes recorded, weighed and the determination of Fibre, Brix, Sucrose, Purity, Reducing Sugars and the Extraction percentage was made. A summary of the statistical interpretation of the analysis for the following factors is given below :—

(i) Brix per cent. of Juice.

Lands—Difference due to lands significant in January, February and March. Wet land gave significantly higher brix throughout.

Varieties—Difference due to varieties significant in January, February and March. Co. 421, and Co. 312 gave the highest and lowest brix per cent. respectively. Interaction between varieties and lands not significant during any of the months.

(ii) Sucrose per cent. of Juice.

Lands—Effect due to lands significant in December, January and February. Wet land gave significantly higher sucrose per cent.

Varieties—Difference due to varieties significant in January, February and March. Co. 421 and Co. 312 gave the highest and lowest Sucrose per cent. respectively. Interaction between varieties and lands significant only in January. Co. 419 responds better to the change of land.

(iii) Purity per cent. of Juice.

Lands—Difference due to lands significant only in December and January. Wet land gave higher purity throughout.

Varieties—Effect due to varieties significant only during December and January. Purity per cent. is highest in Co. 312 during December and January. In February and March Co. 421 shows the highest purity.

Interaction between varieties and lands significant in January. Co. 419 responds better to the change of land.

(iv) Weight per cane in ounces.

Lands—Difference due to lands significant in February and March.

Garden land showed higher weight per cane throughout.

Varieties—Effect due to varieties significant in December, February and March. Co. 419 showed the highest weight per cane in December and March and Co. 312, the lowest in all the three months.

Interaction between varieties and lands significant only in March. The weight per cane of Co. 419 is considerably higher in Garden land.

The average number of tillers per row does not show any striking difference between the wet and garden lands. The per cent. of flowering is more in the wet lands for the varieties Co. 419 and Co. 312, Co. 421 did not flower in the experimental plots in both the wet and garden lands.

Leaf sheath samples of all the three varieties in the wet and garden lands were taken in December, February and March and the organic Nitrogen determined. The mean of the four replications shows slightly higher percentage

of N in the garden lands for the varieties Co. 419 and Co. 421 throughout the three months, while Co. 312 shows slightly higher N per cent. in the leaf sheath in December and February in the wet lands, though in the month of March the percentage of N in the leaf sheath is higher in garden lands. The higher percentage of N in the leaf sheath of the garden land varieties in general, though there is not much difference in the Nitrogen content of the two soils is interesting in this connection.

(2) *Manufacturing qualities of Co. canes.*—Tours to the different sugar factories in India with a view to collect data on the manufacturing qualities of the Co. and other varieties crushed by them and the relationship of the varieties to the factory recoveries form an important part of the programme of the Chemist.

The West Bengal factory crushes Co. 313 and its recovery is satisfactory (10.88) and that of the Rayagada factory in Orissa is also satisfactory (10.37). This factory crushes Co. 419 and Co. 527. The Madras factories fall into 3 categories : (i) The Seethanagaram area which crushes Co. 419, Co. 421 and Co. 527. The recovery is quite satisfactory and of the order of 10.18 (ii) The Anakapalle, Ettikoppaka and Samalkot area which crushed only Co. 419. The recoveries are of the order of 9.33, 10.30 and 8.80 respectively and can be improved provided early ripening varieties like Co. 449 and Co. 527 are introduced. (iii) The Vuyyur, Nellikuppam and Pugalur area in which the recoveries are low and of the order of 8.19, 8.50 and 8.35 respectively. In spite of the fact that an early variety like Co. 527 is grown at Vuyyur and an early variety like Co. 281 is grown at Nellikuppam the recoveries are low. At Pugalur only Co. 419 is grown.

The factory behaviour of the varieties are very briefly given below :—

- (i) Co. 281—This variety is crushed only at Nellikuppam and it has been found to be the best as regards manufacturing qualities. The quality of the juice is good with high purity and low glucose. In the mill the performance of the variety is very good, the bagasse coming out dry and well exhausted in powder form. The juice clarifies very easily giving sparkling juice. The press mud is compact and can be handled easily. Because of the high ash content there is considerable scab formation in the evaporators. The purity of the molasses is higher than usual.
- (ii) Co. 313—At Plassey in West Bengal, this variety has not given the mud trouble and filtration trouble which it gave in Bihar some years ago and is satisfactory in every respect. The press mud is not quite hard. It gives high recoveries in the beginning of the season and keeps up its high quality up to the end of the season.
- (iii) Co. 419—This is a late maturing variety. It gave the peak recoveries of 11.62 in the first week of April in Ettikoppaka and 10.17 in the end of February at Anakapalle. Its behaviour in the manufacturing house is extremely good. The fibre comes out well pulverised and dry. The juice is very pure and light in colour and clarification is very easy and good. At Anakapalle very good clarification is obtained by using little lime (0.12—0.14 per cent.). The press mud is hard and well set.

- (iv) Co. 421—In the factory at Plassey, West Bengal, this variety is said to cause difficulties in the mill because of its long and tough fibres. But at Seethanagaram and other factories in that area this variety does not give this trouble and its behaviour in the manufacturing house is very satisfactory.
- (v) Co. 527—The behaviour of this variety in the factories is very satisfactory. High recoveries early in the season are obtained and juice is of high purity and clarifies well.

(C) Cyto-genetical Studies

Cytogenetical studies have been underway for some years at the Coimbatore Station with a view to a better understanding of the genetical make-up of the various species of *Saccharum* and also for building up ultimately, breeding stocks of known constitution.

Cytological studies of *Erianthus* types and *Erianthus* crosses initiated last year were continued and have shown the occurrence of polyploidy within the genus, the various types falling under four chromosome groups, viz., $2n = 20$, $2n = 30$, $2n = 40$ and $2n = 60$. The pentaploid or $2n = 50$ type which is missing in the above series has now been synthetically produced by crossing *E. munja* (munja grass $2n = 60$) with *E. Ciliaris* ($2n = 40$).

Certain species of *Erianthus* are characterised by the presence of an awn on the fourth glume, exserted beyond the spikelet. It is interesting that a few F seedlings of the cross *Narenga prophyrocoma* $\times$ *Sclerostachya fusca* showed the above character and they have been isolated for further study. Acetocarmine smears of a few of them showed the presence of 15 bivalent chromosomes, the sum of the gametic number of the parents. It would thus appear that an interaction of the complements of the two genera, *Narenga* and *Sclerostachya* gives rise to hybrids with exserted awns in their spikelets. As certain *S. officinarum* types also show the presence of an awned IV glume in their spikelets, it would appear that the question of the origin of the various species of *Saccharum* and allied genera is highly complicated and would require a critical study of the inter-relationships of the various genera for its solution.

The form 'Ikra' which was collected as one of the types of *Sclerostachya*, showed, as previously reported, certain morphological characters which were more or less intermediate between two genera *Sclerostachya* and *Narenga*. The floral characters of the selfed progeny derived from the variety 'Ikra' were examined. It was seen that while 'Ikra' has a sessile and a pedicelled spikelet in the nodes of the inflorescence a few of the selfs showed the presence of both pedicelled spikelets in the nodes of the inflorescence, a feature characteristic of the genus *Sclerostachya*. The recovery of the parental types from the selfed progeny gives additional support to the view that 'Ikra' is a natural hybrid between *Narenga prophyrocoma* and *Sclerostachya fusca*.

Another line of work taken up at the station has been an attempt at the breaking up of the Amphidiploid constitution of the hybrid seedlings with a view to obtaining plants with the haploid complements of *S. spontaneum* chromosomes. For achieving this, systematic back-crossing of the *S. spontaneum* derivatives with suitable male parents, is underway, and a few of the resultant seedlings are being examined cytologically for the selection of suitable types for further study.

(D) *Physiological studies*

The object of these studies is to find out the physiological factors which form the basis of flowering in sugarcane with a view to enhancing the efficiency and scope of cane breeding. [The studies are at present confined to :—

(a) Chemical composition of flowering and non-flowering varieties (b) Study of the photoperiod factor in relation to flowering and (c) Studies on the effects of manurial, chemical and irrigation treatments on flowering in sugarcane.

Studies into the chemical composition of the flowering variety Co. 421 and the non-flowering variety Co. 468, under manurial and irrigation treatments were continued during the year. The non-flowering variety Co. 468, irrespective of the manurial treatments, has arrowed under alternate day irrigations only, whereas Co. 421 has arrowed generally under all the treatments. Nitrogen content in both the varieties is inversely proportional to the frequency of irrigations. In the bottom portions of the stem both the sugar and nitrogen contents in Co. 421 were higher than in Co. 468. But in the top portions of the stem the carbohydrate content is higher and nitrogen content lower in Co. 468 than in Co. 421. On the whole, C/N ratio was throughout at a higher level, in Co. 468 than in Co. 421. In both the varieties C/N ratio attains a maximum at the arrowing phase after which there is a definite decline.

The photoperiodic, irrigation and manurial treatments gave interesting results and the disparity in flowering between early and late varieties was successfully bridged up by the treatments. In the early flowering varieties Co. 285, Co. 421, and Co. 639 extra darkness or extra light over the normal day light photoperiod coupled with 9-day cycle-irrigation tends to delay arrowing, the maximum lengthening of the flowering periods being attained in 10-hour-day and 16-hour-day photoperiods. The percentage of flowering was however, definitely higher in 10-hour-day photoperiod than in 14-hour-day or 16-hour-day photoperiod. In the late flowering varieties Co. 626 and Co. 616, there appears to be an indication of hastening and production of highest percentage of flowering under 10-hour-day photoperiod and 2-day-cycle irrigation.

In irrigational treatments, lower frequency of irrigations delayed arrowing in the early variety Co. 745 and late variety Co. 468 flowered earlier with copious irrigation. In both Co. 745 and Co. 468, however, the percentage of flowering was found to be more under frequent irrigation.

(E) *Pests and Diseases*

(1) *Pests*.—The early shoot borer, *Argyria* sp. was found to be common and attacked the cane crop one month after planting. The peak of the attack was reached in the third month after which the attack decreased and was over by the fifth month. The attack was, in certain varieties as high as 20 to 30 per cent. the top shoot borer, *Scirpophaga* sp. was not serious, the percentage of attack being never more than 5 per cent. The attack started four months after planting and continued right upto the end of the crop. The stem borer, *Diatraea* sp. began its activities with cane formation in the varieties and continued right upto the time of harvest. The root borer, *Emmalocera* sp. was noticed only rarely. Pyrilla was also noticed but the attack was mild. The White fly, *Aleurolobus* was quite common and particularly so in the new *spontaneum* collections. It was brought under control by three sprayings of Gammaxene (P. 520).

Termite attack was rather heavy. Tar emulsion treatment with irrigation water was given but was not very effective. A preliminary experiment has been laid out to find whether by treating the cuttings in coal tar and dipping the setts in 0.5 per cent. solution of Gammexane and DDT (separate treatments) for 30 minutes before planting the percentage of attack could not be minimised.

In addition to the above, experimental work has been started on :—(i) Borer entry studies coupled with rind hardness tests, (ii) Insect activity during moon-lit and dark nights and (iii) detailed notes on the varieties belonging to the various species of *Saccharum* with reference to borer attack.

(2) *Diseases*.—Mosaic was noticed to be heavy in certain varieties and the affected plants were rogued out. The *Saccharum sinense* varieties are still not quite free. The observations collected month by month show that (i) where there was an attack in the young stage of the crop, the percentage of attack during subsequent months was rather higher, while in the varieties which were attacked at a later stage the infection was not heavy in the subsequent months and (ii) natural transmission of mosaic at Coimbatore seems to be rather high.

There were a few cases of smut. Pinapple disease was noticed on some canes of Co. 413 and Co. 419. A few cases of red-stripe, *Cytospora* and twisted top were noticed.

The resistance to Red Rot of Co. 213 and Co. 59 varieties of which Co. 213 is the parent were tested. A separate plot was laid out for this experiment and the varieties were inoculated when the plants were 5 months old with a virulent strain of *Colletotrichum falcatum* Went, the culture of which was kindly supplied by the Head of the Division of Mycology, Indian Agricultural Research Institute, New Delhi. Seven months after inoculation the canes were split and the linear spread of infection noted both above and below the point of inoculation. The linear spread of infection varied from 5.1 inches to 60 inches. The linear spread in Co. 213 was 26 inches. Eleven varieties showed more linear spread than Co. 213 and 45 were found to be less susceptible. Co. 374 was the most affected while Co. 302 and Co. 634 showed the least infection.

Ten *spontaneums* were also tested for Red-rot resistance and six of them may be said to be resistant.

The inoculation experiments on Co. 213 and sixty other canes of which Co. 213 is the parent, are proposed to be repeated next season for confirmation. In addition it is also proposed to take up (i) Co. 301 and 25 Co. canes of which Co. 301 is the parent, (ii) Co. 331 and twenty two Co. canes of which Co. 331 is the parent and (iii) twenty three forms of *S. spontaneum* collected by the Spontaneum Expedition Scheme.

A beginning was made in the work of evolving disease resistant varieties by trying to infect the seedlings in the young or seed pan stage with smut. But the technique would need to be perfected as the seedlings after (i) seeds have been mixed with smut spores and (ii) seedlings have been sprayed with smut spores suspension have not shown the smut infection. As for Red-rot the seedlings can be inoculated only at the stage at which cane formation has taken place and for this the 2nd ground nursery stage would appear to be more suitable than the 1st ground nursery stage.

Sugarcane Sub-station, Karnal

(1) *Live Herbarium*.—The live collection has now increased to 761 varieties consisting of 400 Co. canes, 121 North Indian varieties, 102 wild *Saccharums* and allied genera, 107 exotics and the rest miscellaneous.

(2) *Morphological descriptions*.—Complete morphological descriptions of certain of the Co. 600 series were recorded together with line drawings etc. In addition, the popular Co. varieties in cultivation in the different provinces were also described with a view to comparing these descriptions with those done at Coimbatore and noting the variation in characters, if any. The characteristics of the epidermal peelings of the stem and leaf of Co. canes are being recorded to see if they would serve as additional characters for identification.

(3) *Notes on early habit*.—For recording the early habit of varieties the angle which the shoot makes with perpendicular is measured with an instrument. This will enable a better idea of the habit of the varieties.

The following Co. canes have withstood drought and cold satisfactorily and the question of their utilisation in breeding at Coimbatore is under consideration: (i) Co. 618, (ii) Co. 620, (iii) Co. 622, (iv) Co. 680 and (v) Co. 683.

Spontaneum Expedition Scheme

An exploration, survey and collection of the various forms of *S. spontaneum* and allied species occurring throughout India has now been organized and this is the second year of the work of the Scheme.

The exploration of *S. spontaneum* and allied species from South India (Madras, Travancore, Mysore and Coorg) has now been completed. All the important areas in the forests along the hills (*viz.*, the Western Ghats, The Eastern Ghats, Shevaroy, Javadi, etc.), and along the main riverine tracts in the plains and along sea-coasts have been surveyed. A total number of 152 types (SES 1 to SES 152) have been collected; among these, 130 collections belong to *S. spontaneum*; 10 to *Erianthus arundinaceus*, 10 to *Sorghum halapense*, 4 to *Bambusae*, and 35 are grasses.

The *spontaneums* show a good amount of adaptability under divergent ecological conditions: *e.g.*, (i) *Altitude*—sea-level to 4,000 ft. (in South India); (ii) *Soil*—mainly on coarse sand mixed with boulders and pebbles, but also on loam and clay soil (while spreading), both in saline and ordinary soil; (iii) *Temperature*—from areas with a minimum of 40°F. to areas with a maximum of 124°F; (iv) *Rainfall*—from areas with an average annual rainfall of 20" or less to areas with 200" rainfall; (v) *Association of plants*—in absolutely xerophytic association of dry scrub jungle to areas with mixed Deciduous and Evergreen forests.

The *spontaneums* also show a good amount of variation in their morphological characters. In consideration of the range of ecological and morphological variations, determined from the extreme and intensive variations of the *spontaneums* in the living state, the following useful agro-economical characters are very likely to be available in the present *spontaneum* and *Erianthus* collection:—

- (i) Drought resistance.
- (ii) Frost resistance.
- (iii) Salt resistance.

- (iv) Withstanding waterlogging.
- (v) Higher altitude distribution.
- (vi) High Rainfall distribution.
- (vii) Erect habit with close stand.
- (viii) Tallness in habit.
- (ix) Profuse tillering.
- (x) Fast growth.
- (xi) Protogyny in flowers.
- (xii) Higher sucrose content.
- (xiii) Disease resistance.

All except 15 types, which are dead, are being preserved as live collections at the Coimbatore Station and the following records are being maintained :—
 (i) Germination ; (ii) Comparative tillering capacity ; (iii) Rate of growth of elongation for each type in each month in comparison to other types (iv) Time of flowering and period of full flush ; (v) Time of opening of flowers, anthesis and availability of pollen grains ; (vi) Presence of protogyny in the various types ; (vii) Chromosome number determination ; (viii) Determination of percentage of sucrose, brix, etc., and (ix) Incidence of pests and diseases in various seasons.

Programme of work (1949-50).

Breeding with particular emphasis on specialised characters as 'early' and 'late' maturity, disease and pest resistance, non-pithy character of the stem and chewing quality.

Studies on (i) occurrence of starch in the stem in species and hybrid seedlings of *Saccharum* to ascertain its value as a specific character, (ii) cell size and starch content of leaf as correlated with maturity, and (iii) moisture content of leaf sheath as index of early maturity.

Cyto-genetical studies bearing on the mode of inheritance of characters in *Saccharum* and allied genera as also on speciation in *Saccharum* and evolution of the cultivated types of sugarcane.

Physiological studies on chemical composition of flowering and non-flowering cane varieties and the initiation of reproductive phase in non-flowering canes by photoperiod treatments and chemicals.

The relationship of anatomical and other characters to disease, pest, drought and frost resistance in cane hybrids..

Determination of albuminoids, colloids, etc., in the seedling canes before they are released from Coimbatore and a study of the manufacturing qualities of the Co. canes.

The exploration and collection of wild forms of *Saccharum* and allied genera.

REPORT OF THE DIVISION OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY (1948-49).

I. RESEARCH.

Agricultural Chemistry :

1. Phosphatic manuring of berseem (1946-47, B. V. Subbiah and U. Sen Gupta).

OBJECT :—Effect of phosphatic manuring of berseem on soil fertility.

A berseem-guar rotation is being followed for 3 years in which the berseem crop is fertilized with 50 and 100 lb. P_2O_5 per acre as superphosphate with

and without 80 lb. K_2O as potassium sulphate. After 3 years the effect of these treatments on soil fertility will be assessed by growing wheat in Rabi and maize in Kharif.

The berseem crop taken in 1947-48 was analysed for nitrogen, P_2O_5 and CaO . The uptake of nitrogen and CaO by the crop was not affected by the application of phosphate but the uptake of the latter was increased. The addition of potash seems to diminish the uptake of phosphate. The amount of P_2O_5 in the crop under the different treatments are given below along with the data for the previous year.

TABLE 1.

Treatment	lb. P_2O_5 in the crop.	
	1946-47	1947-48
No manure	38.3	36.1
50 lb. P_2O_5	52.4	51.1
100 lb. P_2O_5	64.4	60.1
50 lb. P_2O_5 + 80 lb. K_2O	47.3	49.7
100 lb. P_2O_5 + 80 lb. K_2O	60.4	49.7

The control plots contained 0.007 per cent. more nitrogen than at the start while the fertilised plots showed an increase ranging from 0.009-0.019. P_2O_5 content also showed an increase of 0.011-0.024 per cent. while lime was depleted to the extent of 0.05-0.17 per cent.

2. Studies on wild leguminous plants (1948-49, M. A. Idnani and R. K. Chibber).

The scheme for nitrogen fixation originally contemplated an examination of wild leguminous plants. A study of the chemical composition of such plants and trees has been undertaken to investigate the suitability of the leaf as green manure or fodder. 43 varieties were collected round about Delhi and analysed for nitrogen, P_2O_5 , K_2O and CaO . The majority of these contained over 2 per cent. nitrogen in the green matter, the maximum found being 5.9 per cent. in *Cassia Occidentalis*. The content of nitrogen, in general, compares favourably with that present in the usual green manure and fodder crops like berseem (3 per cent.) and sannhemp (2.3 per cent.). This indicates the possibility of utilizing these materials for green manuring wherever available.

The leaves were, in general, also found to contain appreciable amounts of lime (3.7 per cent.) and phosphoric acid (0.5-1 per cent.). Their suitability as fodder is being investigated.

3. Conservation and utilisation of human urine as manure. (1948-49, M. A. Idnani).

The total quantity of nitrogen in human urine in India has been estimated to be 1.5 million tons per annum, in addition to substantial amounts of phosphoric acid, potash, lime and other salts. The possibility of conserving these manurial constituents, in absorbing materials is being investigated. Soil, sand, saw-dust, charcoal dust, coal ash, dry leaves and farm yard manure absorb urine. The concentration of nitrogen could be increased by repeated soaking and drying in the sun. The loss in the process amounts to about 6 per cent. of the added nitrogen when saw dust is used. In soil, the loss of nitrogen amounted to 2 per cent after soaking and drying 3 times.

A special urinal based on this principle has been designed.

The material thus obtained is comparable in manurial value, if not better than sulphate of ammonia.

TABLE 2

Yield of wheat grains from 30 plants (grams).

Treatment	Urine absorbed in			Amm. sulphate	Control
	Soil	Charcoal	Saw dust		
	26.6	28.0	27.4	22.8	11.5

The trials are being repeated.

Soil Chemistry

4. Soils of Andaman Islands. (1948-49, K. B. Shome and D. P. Motiramani).

At the instance of the Ministry of Agriculture 16 soils collected from Andaman Islands and sent to the Institute were analysed. The soil samples relate to Lurn zig, Mid Boratang ; Griel Kaicha Baratang West ; John Lawrence island, Henry Lawrence island and Havelock island. Air dried soils contain a fairly high proportion of hygroscopic moisture consistent with the high content of clay and organic matter. The soils are generally rich in nitrogen and poor in other plant nutrients. The silica-sesquioxide ratio is mostly below 2.0 indicating that the soils have been formed under conditions of heavy leaching and that the clay mineral is kaolinitic. The summarised statement of the analytical data is given below.

TABLE 3

Hygroscopic moisture	..	..	..	..	0.78—5.93
Clay	..	..	..	..	27.00—44.00
Organic carbon	..	..	..	..	1.00—1.90
Organic Nitrogen	..	..	..	..	0.128—0.251
Total Phosphoric Acid	..	..	..	..	0.04—0.10
Available Phosphoric acid	..	..	..	..	0.0015—0.007
Total Potash	..	..	..	..	0.257—0.533
Available Potash	..	..	..	..	0.011—0.025
SiO ₂ /R ₂ O ₃	..	..	..	..	1.85—2.80

Soil fertility.

The following soil fertility investigations were started at the suggestion of Dr. J. N. Mukherjee, the Director of the Institute.

5. Effect of different rotations and manurial treatments on the nutrient status of soils.

(1946-47, B. V. Subbiah, D. P. Motiramani and S. P. Jain).

OBJECT :—Effect of heavy doses of fertilizers, with and without a legume in rotation on crop yields and soil fertility.

In the first set of these experiments (Series IV) the rotation is wheat-maize. Fertilizers are applied to the wheat crop. In the second set (Series V), the rotation followed is wheat-maize-peas-maize, the rabi season crops being fertilized as in the first set. The crops were analysed for nitrogen, P₂O₅ and CaO.

No marked differences in the composition of the crops was observed.

The results of soil analysis at the start of the experiment and in 1947 and 1948 are given in the following table.

TABLE 4.

Series IV					N%	P ₂ O ₅ %	K ₂ O%	CaO%
	Initial	..	..	..	0.073	0.084	0.96	0.74
	1947	..	..	..	0.062	0.089	0.51	0.56
	1948	..	..	..	0.058	0.090	0.48	0.63
Series V					N%	P ₂ O ₅ %	K ₂ O%	CaO%
	Initial	..	..	..	0.078	0.10	0.97	0.69
	1947	..	..	..	0.066	0.098	0.65	..
	1948	..	..	..	0.075	0.096	0.66	0.68

The initial fertility status of the soil was fairly good. In series IV where a cereal after cereal rotation was followed the contents of N, K₂O and CaO have all decreased but in series V where a legume, peas has been included the contents of N and lime have almost remained constant and the decline in potash content has been less. The content of P₂O₅ has been almost constant in both series.

6. Experiments in the lysimeter blocks. (Raised plat experiments). (Rabi, 1945-46, W. V. B. Sundara Rao and K. G. Tejwani).

Experiments of Parr and Bose (Indian Farming Vol. V, 1944) indicated that berseem gave very good response to phosphate fertilization. Berseem and cowpea were grown for 3 years in Rabi and Kharif respectively after which wheat was grown. It was thought desirable to investigate if it is possible to build up soil fertility as indicated by the yield of wheat following only one crop of berseem and of cowpea.

Also the effect on soil fertility of directly fertilising wheat in a cereal rotation was studied. The leachates from different treatments were also analysed.

Two types of 2 years—4 course rotations, one purely cereal and another including legumes, have been used to study the above aspects as also the difference between the two rotations.

The rotations are :—

1. (cereal) Wheat-Marwa (Eleusine coracana)-Wheat-Marwa.
2. (legume) Berseem-cowpea-wheat-cowpea.

The crops and treatments are shown below.

TABLE 5

Lysimeter No.	Two legumes in the rotation		Pure cereal rotation			Legume rotation Started in 1946-47		
	1	2	3	4	5	6	7	9
Season	..	0.B1	P1B1	0.W	N.W.	P1.W	Npl.W	
1945-46 Rabi	..	C	C	M	M	M	M	
46 Kharif	..	W	W	W	W	W	W	0B2
1946-47 Rabi	..	C	C	M	M	M	M	C
47 Kharif	..	0.B2	P2B2	0.W	N.W.	P2.W.	Np2.W.	W
1947-48 Rabi	..	C	C	M	M	M	M	C
48 Kharif	..	W	W	W	W	W	W	0.B1
1948-49 Rabi	..							P1B2

0 = no manure ; P1 and P2 = P₂O₅ at 100 and 200 lbs ;

B1 and B2 = Berseem seeds rate at 30 and 60 lbs ; W = Wheat ;

M = Marwa and C = Cowpeas. N = 80 lbs. N as ammonium sulphate.

The fertilizers were applied to the first crop in each case and there was one plot for each treatment.

A fairly high dose of P has been used because of the high phosphatic requirement of berseem.

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The main findings of these studies are :—

1. Soil fertility is better built by following a legume rotation than by following a purely cereal rotation.
2. The percentages of N in wheat grain are given below. The value in the legume rotation was higher than that in directly fertilized wheat.

TABLE 6.

Lys. No.	Nitrogen percent	
	1946-47	1947-48
1	2.86	..
2	2.28	..
3	1.71	1.42
4	1.86	2.10
5	1.41	1.81
6	1.72	1.99
7	..	2.72
9	..	2.37

The results will be discussed in next year's report.

7. Indicator plant studies. (1946-47, W.V.B. Sundara Rao and A.B. Ghosh).

The object of the experiment is to observe quickly indication of mineral deficiencies of soils, from plant symptoms and by agronomic observations in pot culture experiments.

In the year under review in Kharif 1948, two soils, one from Top Block IA (I) and the other from Main Block IID (II) were selected for pot experiments after chemical analysis. II was definitely richer in citric acid soluble P_2O_5 . The analytical data are given below :—

TABLE 7.

Constituents.	Percentage on oven dry basis	
	Top Block IA	Main Block IID
	(I)	(II)
Loss on ignition	2.26	4.50
HCl soluble P_2O_5	0.07	0.07
HCl soluble K_2O	0.62	0.65
Available P_2O_5 (Citric acid sol.)	0.003	0.022
Available K_2O (Citric acid sol.)	0.013	0.012
Total N	0.04	0.05
NO_3-N	0.5 mg/100g.	0.9 mg/100 g.

(a) Experiments with maize.

N deficiency was indicated in 15 lb. pots receiving PK only, by their pale green foliage, stunted growth and the older leaves drying up rapidly from the tips (firing). The plant in pots receiving NK treatments indicated P deficiency by their dark green foliage, lack of growth and violet streaks on the leaves.

TABLE 8.

Treatment.							Average dry weight of the whole plant (1948).	
							Soil I.	Soil II.
1. No manure	..	..	..	..	..	..	6.4 gm.	9.3 gm.
2. N	..	..	..	..	..	..	9.8 "	16.4 "
3. P	..	..	..	..	..	..	8.8 "	11.3 "
4. NP	..	..	..	..	..	..	20.2 "	24.5 "
5. PK	..	..	..	..	..	..	6.7 "	8.6 "
6. NK	..	..	..	..	..	..	12.5 "	19.2 "
7. NPK	..	..	..	..	..	..	21.7 "	30.1 "

The doses of N, P_2O_5 and K_2O are each at the rate of 100 lbs. per acre. Comparison of the treatments 3 and 5 reveals that K has depressing effect on the yield of crop in Delhi soil. The results are discussed below :—

(i) Nitrogen. In soil I N was on the verge of significance over no manure but NPK and NP were highly significant over PK and P treatments. Since the soil was poor in available P_2O_5 , N alone was ineffective. But in soil II which is comparatively richer in available P_2O_5 , N alone also was highly significant over no manure.

(ii) Phosphorous. In both the soils response to P has only been significant in the presence of nitrogen which is lacking in either case. In both the soils, P and PK are not significant over no manures. PK has shown the least response.

(b) Experiments with Berseem :—

In 1948-49 rabi, berseem was used as the indicator plant with the same two soils using 0, 100, 150, 200, 250, 300 and 350 lbs. P_2O_5 per acre with and without a basal dressing of 60 lbs. N and 150 lbs. K_2O per acre respectively.

With soil I, 40 per cent. of the plants showed reddening symptoms in the control, which decreased to 2.5 per cent. and nil with 200 and 250 lbs. P_2O_5 respectively. Basal dressings alone of $N_{60} K_{150}$ did not appreciably reduce the reddening symptoms. With soil II only 14 per cent. showed these symptoms in the control. P_2O_5 at 150 lbs. per acre reduced it to 10 per cent. With soil I, maximum yield was obtained with P_2O_5 at 250 lbs. and with soil II at 200 lbs.

The results are in agreement with those of previous year.

8. Leaf analysis. (1946-47, W. V. B. Sundara Rao and M. R. Chandrashekher).

The purpose of this experiment is to assess deficiencies of nutrients in soils by periodic leaf analysis of wheat in the plots of the New Manurial Series, Pusa, (Rabi 1946-47). It was noticed that high yields were associated with high values of the "intensities" and with an increase in nitrogen of the NPK unit. The NPK unit for optimum growth of wheat under the conditions of experimentation was found to be N, 66.49 ; P_2O_5 , 6.85 ; and K_2O , 26.66 while the intensity was 6.54.

This year the leaves of the barley crop of the Permanent Manurial Series Pusa were analysed. A slight modification was introduced in the interpretation of this year's results.

From a study of the curves showing the N, P_2O_5 , and K_2O percentages in the leaf, it appears that an accumulation of nutrients in the leaves, is harmful to the nutrition of the plant in the early stages resulting in diminished yield. On the other hand a gradual and sustained mobilization of the nutrients from the leaf to other parts of the plant is a characteristic feature of the fertile plots. The crop in plots receiving nitrogen had in general a higher initial N in the leaf than that in the other plots. The P_2O_5 and K_2O treated plots showed a similar behaviour.

9. Pot experiments with green manure (sannhemp), castor cake and F.Y.M. and their ashes. (1948-49, W. V. B. Sundara Rao and K. G. Tejwani).

The purpose of this experiment is to compare the relative effects on the wheat crop of (a) organic manure (F.Y.M. sannhemp, and castor cake), (b) of their ashes, (c) their ashes + nitrogen lost in ashing. For comparison NPK (artificial only) as present in F.Y.M. at the rate of 80 lbs. per acre were also added to complete the series. The idea was to ascertain the relative contribution made by the inorganic constituents of organic manure, that is, by all of them together, all of them excepting N, NPK only and by the organic matter alone. It has to be taken into consideration that the process of ashing may change the availability of the inorganic constituents.

15 lbs. pots were used in these experiments and the number of plants in each pot was 6. The results show that NPK and NP treatments as inorganic fertilizers gave the best yields. Next in order were the ashes plus N and N alone which did not differ significantly amongst themselves. The experiment is being continued.

Micronutrients.

10. Manganese contents of Indian soils. (1948-49, T. D. Biswas).

20 samples from 40 profiles from soils which have not been disturbed for years, from all over India were analysed for their contents of manganese in the form of water soluble, exchangeable, reducible, active *i.e.*, the sum of water soluble, exchangeable and reducible, and total. Wide variations were observed in the contents of the different forms. The amount of water-soluble Mn varied from nil to 5.6; exchangeable Mn from 1.6 to 62.6, reducible Mn from 6.0 to 828.0, active Mn from 17.0 to 833.0 and total Mn from 149.5 to 1656, all expressed as p.p.m.

Data on exchangeable, active and total manganese have been analysed statistically to find a correlation with climate. The results are shown below :—

TABLE 9.

Exchangeable Mn.	Climatic group	Perhumid	humid	arid	semi-arid
	Means in p.p.m.	37.03	20.13	15.70	13.7
	S. E _m	±6.41	±5.66	±3.48	±4.4
Active Mn	Climatic group	humid	Semi-arid	arid	per-humid
	Means in p.p.m.	319.98	271.19	115.19	74.17
	S. E _m	±54.15	±41.94	±81.23	±61.4
Total Mn	Climatic group	humid	Semi-arid	arid	per-humid
	Means in p.p.m.	802.44	785.83	529.00	461.66
	S E _m	±109.05	±84.47	±163.58	±123.65

Soils of the perhumid zones are very low in active manganese. The same is true also of calcareous soils. Crops grown in these soils and climatic con-

ditions are likely to respond to manganese. Considering the distribution of active and total manganese with the depth of the profile, four patterns are found : (i) accumulation either in the surface or in some lower depths (ii) increase with depth (iii) decrease with depth (iv) uniform values throughout. The influence of such factors as pH, CaCO_3 , clay content and organic matter of the soil on the different forms is being studied.

11. Work on deficiency of gram. (1946-47, S. C. Dass).

In "Top yellowing" and "bronzing" diseases of gram, no pathogenic organisms have been found to be associated. These are being studied in relation to their nutritional deficiencies since 1946-47. Previous work on the analysis of healthy and diseased leaf samples showed "top yellowing" to be associated with lower content manganese, and "bronzing" with lower P_2O_5 contents as compared to the healthy plants. Also, the diseased plants showing either "top yellowing" or "bronzing" symptom contained less boron than the healthy ones. In the year under report the analysis of leaf samples of healthy and diseased plants showing symptoms of "bronzing" and "top yellowing" were carried out to confirm the above findings. These results which are tabulated below are in conformity with those obtained in previous years.

TABLE 10.

Year					P205%	Mn p.p.m.	B p.p.m.	N%
1946-47	..	..	Bronzing	..	0.35	94.8	25.3	
			"	..	0.39	100.0	26.0	
			Top yellowing	..	1.01	78.0	28.6	
			Healthy	..	0.68	118.6	36.4	
			"	..	0.73	101.6	34.7	
1947-48	..	..	Bronzing	..	0.38	89.5	45.2	
			"	..	0.33	95.1	42.2	
			Top yellowing	..	0.58	68.0	40.5	
			Healthy	..	0.57	98.1	55.1	
			"	..	0.53	99.0	57.0	
1948-49	..	..	Bronzing	..	0.44	94.0	31.0	7.8
			"	..	0.45	90.0	30.8	6.9
			Top yellowing	..	0.86	45.0	31.2	4.0
			"	..	0.88	55.0	31.5	3.2
			Healthy	..	0.80	95.0	41.5	3.5
			"	..	0.84	100.0	40.6	3.5

Plants showing symptoms of "bronzing" were found to contain less P_2O_5 as compared to healthy ones. Nitrogen content on the other hand was found to be high in these plants. In the "top yellowing" disease of gram, the diseased leaves were associated with low content of manganese and there was a slight excess of P_2O_5 content as compared to healthy leaves. As in previous years, the boron content was less in these leaves.

Examinations of the soils at the root zones of "top yellowing" and "bronzing" plants indicated a high salt content as compared to soils at the root zones of the healthy ones. The soils are slightly alkaline, pH values being 7.8 to 8.0.

12. Micronutrients in grasses, forage crops, fodder, feeds and concentrates. (1948-49, N. P. Datta, and N. R. Datta Biswas).

Cobalt and copper have been linked with certain nutritional disorders in animals. This work has been taken up with a view to study the nutritional studies of grasses, forages and fodder etc., fed to the I.A.R.I. dairy cattle,

as also of the various grasses grown under identical conditions at the I.A.R.I. grass nursery. Protein, ether extract, crude fibre, CaO , P_2O_5 are being determined by the Biochemistry Section. The nitroso-R-salt has been used for the estimation of trace cobalt (0.05-2.0). For certain grass samples which contain a high amount of silica it has been found necessary to volatilize the silica with HF . With this treatment both wet and dry methods of ashing give good results, indicating that cobalt is not lost between $450-550^\circ\text{C}$. Four grass samples have been analysed; One sample (Lab. No. 840/46) contains 6.5 Co/100 g.D.M. and is almost on the border line for cobalt deficient pastures.

13. Mineral deficiencies in citrus (1945-46). (Scheme of research on minor or trace elements in Indian soils and plant nutrition, the I.C.A.R.).

The object is to study mineral deficiencies especially of micronutrients in citrus orchards. Previous work at the Calcutta University with samples of soils and plant materials from Lyallpur and Satgudi indicated deficiencies of manganese and zinc in these areas. This year samples from citrus in Ferozepur, Coorg and Kodur were taken up for investigation. In Ferozepur, the leaves were smaller in size than normal leaves, the intervenal space markedly chlorotic and the veins green. In Coorg the citrus plant is affected with gummosis, stemborer, top-shoot borer and aphid and with mottle leaf symptoms and dieback. The intervenal chlorosis was more pronounced in older leaves. The symptoms were found more pronounced in neglected orchards which showed considerable die-back. Four places in Coorg (Kutta, Tittimati, Hoddur and Horadur-Suntikoppa) were selected for examination of soils on profile basis and diagnostic injections and spray treatments were carried out. Estimations of different forms of Mn in the soils have been completed. Kutta soils upto a depth of 2' is very low in active Mn; 0.6'', 35.9 p.p.m. Mn; 6-24'', 10.3 p.p.m. From responses to diagnostic injections and spray treatments with various trace elements indications have been obtained of Mn, Zn and Cu deficiencies in Kutta and Tittimati and of Mn and Zn deficiencies in Hoddur and Horadur. In Horadur Fe deficiency has also been indicated.

Analysis of healthy and diseased samples of plant material from Coorg are in progress. Healthy samples contain more Mn and Zn. This corroborates the field diagnosis of deficiencies. Analysis of soils from Kodur show that the soils are all poor in base exchange capacity and active manganese.

The data given in the following table show the Mn and Zn contents of healthy and diseased leaves.

TABLE 11.

Place	Mn (p.p.m.)		Zn (p.p.m.)	
	Healthy	Diseased	Healthy	Diseased
Lyallpur	82.0	35.0	18.0	8.0
Satgudi	53.0	12.0	22.0	15.0
Coorg :	32.4	26.9	8.6	0.6
Kutta	24.3	22.0	38.6	6.4
Tittimati	29.5	11.9	21.7	0.7
Hoddur	36.2	17.7	20.4	12.7
Horadur	49.2	23.8	18.8	1.3
Saniversanthe				

Estimation of copper is in progress.

Physical Chemistry.

14. Chemical, electrochemical and viscous properties of hydrogen clays from typical Indian soils. (1948-49, B. Chatterjee, B. B. Roy and S. C. Das).

For purposes of soil survey and soil classification the determination of the clay fraction of the soil freed from the bases, that is, of the hydrogen clay is very important. X-ray and thermal analytical studies have established that the principal clay minerals found in soils belong to the groups, kaolinite, montmorillonite, hydrous micas such as illite, and the less common attapulgite. The clay fraction of the soil is a mixture of one or other of these principal secondary clay minerals. The determination of the types of clay minerals occurring in soils and their relative proportions are very important current lines of work in the leading agricultural research institutes, and newer methods are being evolved. The reason for this is that the physical and chemical characteristics of the soil and to a large degree the soil behaviour are determined by the nature and content of the clay minerals and their electrochemical properties. These electrochemical properties provide the scientific basis for the understanding of such important properties of soils as base exchange conditions of flocculation and deflocculation, alkaline and saline natures and many other aspects of soil behaviour.

Systematic studies of hydrogen clays and other colloidal constituents of soil have been undertaken in the Physical Chemistry Section.

Chemical analyses and studies of black cotton soils from different localities were undertaken. Hydrogen clays from soil samples from different depths of the profile of a black cotton soil from Indore were studied. Chemical analysis of these hydrogen clays give $\text{SiO}_2/\text{R}_2\text{O}$ and $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratios about 3.0 and 3.6 respectively. These figures as also the presence of non-exchangeable magnesium in the clays amounting to 0.88-0.96 per cent. MgO , suggest that the dominant clay mineral is montmorillonite. These clays however, contain also non-exchangeable potassium amounting to 1.6-1.8 per cent. K_2O , indicating the occurrence of some illite. The proportion of the latter is estimated to be about 20 per cent. when calculated on the assumption that illite has essentially the same structure as montmorillonite with the exception that 15 per cent. of Si^{++} position has been replaced by Al^{+++} and the resulting negative charge is balanced by K^+ . There is very little variation in the chemical composition of the clay at different depths of the profile. These hydrogen clays have, also been found to contain a trace of calcium (about 0.4 per cent.) in the lattice.

The montmorillonitic nature of the clays has been confirmed by the nature of the potentiometric titration curves with bases, pH at the inflexion point and the high base exchange capacity calculated from the titration curves, which are all characteristics of montmorillonite.

TABLE 12.

Base exchange capacity in m.e. per 100 gm.

Horizon in inches	NaOH		$\text{Ba}(\text{OH})_2$		N. $\text{BaCl}_2 + \text{Ba}(\text{OH})_2$	
	at pH 7	at inflexion point	at pH 7	at inflexion point	at pH 7	at inflexion point
0-1½	28.0	59.0(8.6)	46.5	54.0(7.7)	72.5	73.0(7.1)
1½-3	47.5	64.0(8.5)	60.5	65.0(7.5)	78.2	74.0(6.5)
3-6	61.0	70.0(7.8)	69.0	67.0(6.7)	87.5	75.0(5.5)
6-9	63.5	79.0(8.4)	78.5	75.0(6.6)	99.0	84.0(5.4)

(Figures in bracket indicate pH at inflexion point).

The viscosity of 1 per cent. suspension of hydrogen clays with increasing addition of caustic soda increased steadily, reached a maximum value at about 61-68 per cent. neutralisation and then decreased gradually, a property characteristic of montmorillonite. It is thus confirmed that montmorillonite is the principal constituent of clay from black cotton soil from Indore.

Further work with hydrogen clays from lower horizons of the profile is in progress.

Soil survey

Earlier work on soils related to the examination and analysis of surface soils for the major plant nutrients, nitrogen, phosphoric acid and potash and in a few instances the analysis included calcium and magnesium. The inadequacy of such data was later realized. As the first requirement for the preparation of an All India Soil Survey, all the available data on soils and related aspects were collected under the scheme financed by the Indian Council of Agricultural Research and report was drawn up by the beginning of 1946. In the same year a soil survey unit was also established at the I.A.R.I. The unit at I.A.R.I. devoted itself primarily to the survey of the areas under the Institute and its substations. The unit has also rendered advisory service to other Government departments by conducting soil surveys of a reconnaissance type at the following places with specific objectives.

- | | | |
|--------------------------------|-------|--|
| 1. Ajmer Farm | | Pre-irrigation survey. |
| 2. Bhadrak Farm, Lucknow | | Suitability for the cultivation of sugarcane crop. |
| 3. Jubbulpore | | Suitability of the area for establishing Central Cattle Breeding Farm. |
| 4. Rann of Cutch | | To assess the suitability of the area for agricultural purposes. |

Reports on these surveys have been sent. In the case of Bhadrak and Jubbulpore farms land use maps have been prepared.

15. I.A.R.I. Farm. (1947-48, R. V. Tamhane and L. M. Mathur).

In the initial layout of the farm area drastic levelling was carried out involving earth removals and fill ups of 1 to 3 ft. soil. A map showing the topographic changes in the area has been prepared. Due to the heterogeneity and disturbances caused by levelling the standard deviation in experiments is generally high. Very often there is no agreement between replicated experiments. In a number of cases the yields from control plots are higher than those from treated plots. For a proper evaluation of the experimental data and to understand the salinity of specific areas it became necessary to examine the soils and prepare soil maps of the different blocks. A survey of surface drainage of the farm area was carried out and a map showing the defective surface drainage areas was prepared. A study of the fluctuations of water-table has shown that due to the general rise in water-table some areas are likely to be water-logged. Due to this fact also salinisation of soils is gradually spreading in some of the plots. This study is in progress at different periods of the year and appropriate measures will be taken up when necessary. A soil map of the farm is under preparation.

16. Karnal Sub-station. (1947-48, K. V. S. Satyanarayana and L. M. Mathur).

From the available records it is seen that the farm area consisting of 2,154 acres had a long and varied history of breeding work with animals and plants since 1798. In 1936 the farm area came under the control of the Institute. In the past the soils were not examined in detail. Further, large areas are getting salinised and viciating the experimental data obtained from these areas. A detailed examination of the soils was taken up and 19 soil profiles were examined in previous years. During the year under report additional 14 profiles were examined. The soils of the farm area are old alluvial soils (Bhangar). The general feature of the profiles are :—

0-36"—Grey brown silt loam with no clearly developed structure and free of carbonates.

36-72"—Yellowish brown loamy soil usually compact, with black moderately hard concretions of iron and manganese.

Blew 72"—Yellowish brown light textured soil, free of concretions but containing calcium carbonates, sometimes as concretions (Kankar).

The depth variations in the above features follow the relief of the land. At the highest spot the zone of calcium carbonate concretions was met with at 45" depth. Besides irregular bits, calcium carbonate occurs in tubular and rod shapes (over an inch. in length and 1/5 inch. in diameter). In the low lying areas and plots adjacent to irrigation channels due to defective drainage conditions and seepage the salt content is often over 0.2 per cent. and in some cases the soils are deflocculated and are highly alkaline (pH 9.5 to 10.0).

The chemical analysis of 6 profile samples from Block VI was carried out for total nitrogen, organic carbon, calcium carbonate, soluble salts, total and available phosphate and potash. The soils are well supplied in plant nutrients and the soluble salts are within safety limits. A soil map of the farm is being prepared.

17 Rann of Cutch. (1947-48, K. V. S. Satyanarayana).

The Rann of Cutch is a vast expanse of over 8000 sq. miles which is inundated by sea water during a part of the year and the soil is impregnated with salt. A very rapid reconnaissance soil survey of selected areas was carried out in 1947 to assess the suitability of the area for reclamation and agricultural development. The analytical data of the profiles showed that the soils contain considerable amounts of salts chiefly present as chloride and sulphate and in some areas appreciable amounts of gypsum. A profile which had solometric morphology, with a glei horizon (B-G) extending 12"—43" from the surface and containing large amount of gypsum in the B-horizon, was leached with water. The changes in the settling velocities, pH and filtration ratio were measured with successive stages of salt removal. It was found that when the salts were leached out the B-horizon maintained good physical condition while the lower horizons showed tendencies of dispersion.

Hydrogen clays from the three profiles were analysed. The clays were found to contain 3 to 4 per cent. magnesium and 4 to 9 per cent. potassium. The base exchange capacity of H-clays varied between 20 and 40 milliequivalents. The analytical data show that illite and muscovite type of minerals which constitute the mica group of clay minerals are dominant.

18. Petrographic analysis of sand fraction. (1948-49, N. Sen).

To understand the genesis of soils and for their classifications a knowledge of the mineralogy of the parent rocks or soil material is essential. From this point of view the petrographic studies of the fine sand fractions have been

taken up. The fine sands from Rann of Cutch, Karnal, Jubbulpore, Delhi, Indore and Padegaon soil profiles (about 50 profiles) are under study. The data will be presented in the next year.

19. Narmada Valley Project. (1948-49, R. V. Tamhane).

Under the Narmada River Valley Project the proposal is to irrigate the black soils of Hoshangabad, Narsingpur and Jubbulpore districts of Madhya Pradesh. Though these black soils are locally known under various names such as *Katar*, *Mund* and *Marvar*, an examination of 7 profiles in the three districts showed that the soils do not differ much in their characteristics. The rainfall in the area is between 40 to 60 inches and nearly 80 per cent. of it is received in the monsoon months of July to October. The black soils are invariably found to have a brown coloured soil horizon 2 to 3 ft. below the surface. The depth of the soils is over 10 ft. In general the texture is either clayey or clay loam, with a slight variation in texture down the profile. The structure in most cases is cloddy. The detailed analysis of the samples to judge the suitability of the areas examined for irrigation is in progress.

Organic Chemistry.

20. Plant Chemistry. (a) Oil-seeds analysis. (1948-49, G. M. Chopra, A. C. Bose, and K. C. Gulati).

The work has been undertaken with a view to develop a suitable method for the estimation of oil in oil seeds and also to determine the quality of the oil. A fair measure of success has been achieved in developing a semi-micro method for estimation of oils in seeds. The method will be helpful in the breeding programme of the Botany Division.

Some of the results giving the percentage of oils as determined by the semi-micro method and the conventional Soxhlet extraction method are given.

TABLE 13.

Sample No.	oil %	
	Semi-micro method	Soxhlet extract
RR 2	41.15	44.25
RR 10	46.50	46.40
RR 38	48.50	48.40
RR 40	43.15	48.24
RR 68	43.50	48.68

(b) Analysis of Tomatoes. (1948-49, A. C. Bose).

Under investigations on tomatoes with more sweet a taste, varieties of tomatoes have been analysed for their moisture, acid, sucrose and total sugar contents.

(c) Plant Insecticides. (1947-48, Swaminathan, and A. C. Bose).

In connection with the work on high nicotine bearing tobaccos, various samples of tobaccos were analysed. The nicotine content varied from 1.2 to 2.6 per cent.

With a view to prepare nicotine-sulfate concentrates, a semi-commercial method by exposing tobaccos and tobacco wastes to ammoniacal aqueous vapour and subsequent extraction of nicotine from the condensate with kerosene oils is being worked out.

21. Synthetic Insecticides. (1948-49, Sat Bir and K. C. Gulati).

Thiocyano-and halo-derivatives have been prepared starting with indigenous raw materials-terpenes. Preliminary screening tests in the Entomology Division, indicate that some of the compounds possess irradicant insecticidal properties. The compound isobornyl thiocyanacetate, sold commercially under the name 'THANITE' has been obtained in the laboratory in 90-95 per cent. yield.

TABLE 14.

Name of compound	% Purity	Average Mortality CCephalonica		Brassic R. Pseudo After 2 hours
		After 2 days	After 7 days	
Control (10% benzene emulsion)		..	6.7	3.0
Isobornyl thiocyan cetate	97.72	5.5	44.4	100.0
Isobornyl trichlor acetate	90.90	10.0	33.3	52.0

Microbiology.

22. Utilization of phosphates for nitrogen fixation. (1946-47, N. D. Vyas, and J. R. Desai).

(i) Experiments were carried out to examine the residual effect of superphosphate applied in two doses, 60 lbs. and 120 lbs. P_2O_5 per acre, to pea in 1946-47. Three crops, viz., pea, maize and pea were taken, followed by pea in 1948-49. Uniformly high yields upto 81 per cent. increase over control were recorded in plots receiving 120 lbs. P_2O_5 per acre, which suggests that heavy manuring with phosphate may have long term effect upto the 4th crop.

(ii) Experiments were conducted in 1947-48 and 1948-49 with different forms of phosphate on nitrogen fixation through peas. ((1947-48, N. D. Vyas).

It was found that for each 1 lb. of P_2O_5 applied the amount of nitrogen fixed was in the order bonemeal (.83 lbs.) superphosphate (.65 lbs.), Trichi nodules (.32 lbs.), Singhbhum phosphate (.30 lbs.) in the first year, whilst in the year under review the order was superphosphate (.93 lbs.), bonemeal (.86 lbs.), Trichi nodules (.35 lbs.), Singhbhum phosphate (.25 lbs.).

(iii) Studies on the effect of different phosphates and molydenum on green manure crop like sannhemp.

(1948-49, N. D. Vyas, and O. P. Vig).

The experiment was conducted with Delhi soil in glazed earthenware pots each containing 30 lbs. of soil, the height of the column of soil in each pot being 10 inches. Phosphatic manures were applied at the rate of 5 mg. of P_2O_5 per 100 gms. of soil. For molybdenum sodium molybdate was applied at the rate of 2 lbs. per acre. Sannhemp was sown on the 1st of July 1948 and was burried on the 15th September. Periodical observations were taken regarding nodulation and nitrogen fixation. The broad conclusions arrived at upto the time of burying sannhemp are given below :—

- (i) If the crop is not manured with phosphates and if the portions above ground are completely removed there is no gain in soil nitrogen.
- (ii) If the crop is manured with phosphates there is a distanct gain in soil nitrogen even when the portion above ground is removed.

- (iii) If the nitrogen content of the buried crop is taken into account the amount of nitrogen fixed is fairly good. While sannhemp not manured with phosphate, fixed 54.6 mg. of nitrogen per kilogram of soil that manured with superphosphate, bonemeal and rock phosphate fixed 78.46, 72.40 and 66.79 mgs. of nitrogen respectively.

23. Effect of green manure crop (Sannhemp) treated with phosphatic fertilizers and molybdenum on the subsequent crop of wheat. (Pot experiments). (1948-49, N. D. Vyas).

OBJECT.—To increase the yield of wheat by green manuring with sannhemp manured with different phosphates and molybdenum.

Indication was obtained of increase yields with addition of molybdenum. The highest yield was obtained with sannhemp manured with superphosphate and molybdenum. The second best treatment was of bonemeal and molybdenum.

24. Influence of different phosphates on the activities of soil microorganisms. (1947-48, N. D. Vyas).

100 c.c. of Ashby's solution containing one gram of mannite and different phosphates to supply 25 mg. of P_2O_5 were used. The medium was inoculated with one gram of Delhi soil and incubated at 30°C. Nitrogen was estimated after 3 weeks incubation.

The results found tend to show generally that non-symbiotic nitrogen fixing organisms are stimulated by insoluble phosphate of bonemeal and rock phosphate, though to a limited extent.

25. Nitrification. (1947-48, S. C. Biswas).

Experiments on nitrification of different organic manures like oil cake, farm yard manure, and composts, under varying conditions of moisture and temperature in different soils were continued. The nitrogen in sannhemp seeds amounting to 6 per cent. was found to nitrify as rapidly as mustard cake.

26. Nitrogen fixation Scheme (I.C.A.R.). (1947-48, S. N. Nayyar, N. D. Vyas and S. C. Biswas).

The object is to increase the yield of legumes by inoculation with root nodule organisms. Four strains from Pusa, Delhi, Karnal and Coimbatore soils were used for inoculation. Gram inoculated with root nodule organisms produced nodules in red soil where it had failed to do so in the previous year without inoculation. Rahar (late variety N.P.51) was not influenced by inoculation.

27. Palmyra palm gur scheme (Ministry of Agriculture). (1947-48, S. C. Dutt and R. S. Dewan).

The object was to find out a suitable preservative for palm juice. Various preservatives such as Cetavlon (cetyl-trimethyl-ammon bromide), formalin, lissolamine, Octyl cresol furfuran, para-hydroxy benzoic acid, para-hydroxy-ethyl-benzoate, para-hydroxy-propyl-benzote and dibromo-para-hydroxy-benzoic acid, were tried. Cetavlon and formalin appeared to be the best as they proved effective in the concentration of 1 : 10,000, in preserving the juice for 72 and 18 hours respectively. Formalin is however toxic and is undesirable. The method of removing formalin is being investigated.

Experiments were also conducted to preserve the juice with carbon dioxide under pressure with and without preservatives. The results seem to be encouraging.

Fermented juice was examined for the causative organisms and 6 strains of bacteria and 3 strains of yeast were isolated.

Biochemistry.

28. Biochemical studies on tomatoes and ladies finger. (1947-48, M. L. Mathur).

Biochemical studies on certain varieties of vegetables, such as, tomatoes and ladies finger have been taken up. Some varieties were developed by crossing different cultivated varieties with wild ones. Certain crossed varieties of tomatoes studied contained vitamin C much more than the usual average value.

TABLE 15.
Vitamin C content of tomatoes and ladies finger.

Varieties	(mg. per 100 g. fresh sample)	
	Tomato	Ladies finger
Cultivated	23—29	30
Wild	46—79	7
Selection	34—60	14

29. Influence of manures and fertilizers on the nutritive value of cereal crops. (1948-49, N. B. Das, M. L. Mathur and M. R. Chandrashekhara).

During recent years rapid progress has been made in the matter of assessing nutritional values of crops. Chemical and biological methods have been evolved for measuring not only the protein, carbohydrate, fat and mineral contents of food but also the various growth and disease-resisting factors known as vitamins. Interesting results have been reported as to the nutritive value of crops as influenced by heridity, manures and fertilizers, from abroad as well as from this Institute by Vishwanath. It was therefore considered to be of interest to undertake investigations on some of the important nutritive properties, such as, protein, minerals, vitamin B₁ and B₂, nicotinic acid and pantothenic acid contents of wheat grown in the permanent manurial and rotational series at Pusa (Bihar) under different manurial and fertilizer treatments. Nicotinic acid shows no correlation either with the yield or with the protein content. High yields are also not associated with high protein content.

TABLE 16.

Plot No.	Treatment	Yield of grain in lbs.	Crude protein N × 5.7	Nicotinic acid mgms/100 gm.	Thiamin micro gms/gm
3	8000 lbs. F.Y.M.	121	9.93	10.91	3.18
5	Rape cake at 40 lbs. N	82	12.83	11.78	..
9	P+K ..	67	11.27	11.75	..
10	N+P+K ..	92	11.58	11.08	5.49
11	N+P ..	84	10.65	11.76	..
12	Green manure and cereal rotation	68	13.74	11.16	..
13	Control ..	21	14.16	11.97	4.56
14	N+K ..	47	14.55	7.96	..
15	Green manure ..	85	14.23	7.83	..
16	Green manure with phosphatic manuring	170	11.04	11.66	5.24
17	No legume and no green manure ..	14	12.52	13.22	..

The crop of wheat in 1948-49 was abnormal because of late rain during the flowering season and the yield was quite low.

Various methods, such as, biological, microbiological and chemical, have been developed for evaluating the biological value of such crops. Several strains of *Lactobacillus* have been studied for their suitability for the purpose of assaying riboflavin and pantothenic acid.

30. Chemical composition of Indian grasses. (1948-49, N. B. Das and Narindar Nath).

Studies on the chemical composition of selected Indian grasses in cuttings obtained from the same plant at intervals of one month was taken up as similar data are scarce in India. Ten varieties of indigenous grasses, such as *Dichanthium annulatum*, *Amphilophis odorata*, *Iseilema laxum*, *Themada trimula*, *Amphilophis glabra*, *Pennisetum orientale*, *Panicum repens*, *Chrysopogon montanus*, *Seehima nervosum*, and *Heteropogon contortus* collected from different parts of India, have been analysed for crude protein, true protein, ether extract, nitrogen-free extract, crude fibre, ash, silica and insoluble residue, phosphoric acid, lime etc., in cuttings obtained from the same plants at intervals of one month over a period of three months. The analysis of these grasses for micro-nutrient elements was done in the Micro nutrient section. This will be continued for four more cuttings. This system of cutting appears to maintain a high level particularly of protein and phosphoric acid contents. Protein, lime (CaO) and phosphoric acid (P_2O_5) contents vary between 3.72 per cent—10.80 per cent. 0.65 per cent.—1.63 per cent. and 0.45 per cent.—0.93 per cent., respectively. Three of these grasses, such as, *Amphilophis odorata*, *Iseilema laxum*, and *Amphilophis glabra* are also being analysed at four different stages of growth.

31. Studies on the metabolism of soil organisms by soil perfusion technique. (1948-49, N. B. Das and M. L. Mathur).

At the suggestion and active guidance of Dr. J. N. Mukherjee, Director of this Institute, the soil perfusion technique, described by Quastel, has been developed for the study of the metabolism of micro-organisms in Indian soils, under different conditions. The advantages of this method over the current technique are many. This technique ensures standardisation of soil conditions and facilitates homogenous oxygenation and distribution of water in the experimental soil. The course of nitrification is being followed in Delhi soil with this technique as well as with that of Winogradsky. The systems of nitrite and nitrate formation in this soil are also being studied.

Physics.

32. Spectrographic estimation of trace elements and vitamins. (1948-49, C. Dakshinamurti and B. Ramamoorthy).

Work on the quantitative estimation of boron by spectrographic method was started with a medium Quartz Spectrograph in this Division earlier. As greater accuracy in the estimation of all the trace elements is possible with larger dispersion instruments an automatic large Quartz spectrograph has been obtained. This instrument with the necessary equipment ordered for will facilitate the use of the latest techniques such as Cathode layer arc technique where accuracy in estimation will be increased many folds. An intermediate Quartz spectrograph also has been purchased to start Lundegardh flame method for the estimation of major elements. This may also be useful for absorption spectro-photometric measurements for the estimation of vitamin etc.

II. Advisory.

(a) During the year the following samples were analysed and reported, mainly, to various government agencies and also to some private institutes.

Soils	..	..	9
Manures	..	..	14
Fertilizers	..	..	20
Crops & Plants	..	..	6
Feeding stuff	..	..	66
Fodder	..	..	20
Water	..	..	10
Chalk	..	..	8
Salt	..	..	7
Oil seeds	..	..	242
Miscellaneous	..	..	5

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(b) *Supply of bacterial cultures :—*

- (i) Cultures of Senji, shaftal and berseem were supplied to the Superintendent, Cattle Breeding Station, Jubbulpore.
- (ii) Soyabean cultures were supplied to Government Agriculture Chemist, Coimbatore.
- (iii) Berseem cultures were supplied to Jamadar Mahabir Singh of Meerut.

(c) The following notes were prepared during the year :—

1. The use of wool waste as manure, its scope and work done in India (Supplied to Asst. Agricultural Commissioner, I.C.A.R.).
2. Role of minor elements in soil and their effect on forage and feeding cattle (Presented at the Animal Husbandry Wing of the Mysore Session, I.C.A.R.).
3. Ways and means of supplementing the present output of fodder for feeding cattle (Presented at the Animal Husbandry Wing of the Mysore Session, I.C.A.R.).
4. Information on the production of white oil and Vanaspati (Sent to Shri M. M. Ismail, North Arcot).
5. Some aspects regarding the production of power alcohol from Palmyra juice (Prepared for the Council of Scientific and Industrial Research).
6. Soyabean milk (Prepared for the Soyabean Committee, Government of India).
7. Lathyrism. (Prepared for the Director, Nutrition Laboratory, Conoor).

*Programme of work for 1949-50.***I. Agricultural Chemistry :**

1. Conservation and utilisation of human urine as manure.
2. Studies of the wild leguminous plants and trees—Chemical composition of leaves and their suitability for green manuring and fodder purposes—oil and protein content of seed etc.
3. Effect of phosphatic manuring of berseem on soil fertility.*
4. Comparative value of different legumes as green manure.*
5. Effect of heavy application of fertilizers to wheat in the wheat-maize rotation.*
6. Effect of heavy application of fertilizers to the rabi crop in the rotation wheat-maize-peas-maize.*
7. Effect of different types of phosphates on berseem.*

(*In collaboration with the Division of Agronomy).

II. Soil Chemistry.

1. Base exchange studies of soils.
2. Methods of soil analysis.
3. Analysis of soil samples.

III. Soil Fertility.

1. Phosphatic fertiliser requirement of crops in different soils (Pot-experiments).
2. Lysimeter studies (Plant Experiments).
3. Field work based on lysimeter studies.
4. Tissue analysis studies in "Pusa Permanent Manurial Experiment."

IV. Micronutrient.

1. Interaction of soil clays with micronutrient elements Mn, Zn, etc.
2. Cobalt and copper in Indian grasses and fodder and feeds.
3. Manganese in Indian soils.
4. Deficiency diseases of citrus.

V. Soil Physics.

1. Soil moisture studies.
2. Physical properties of soil and clays.

VI. Physical Chemistry.

1. Genesis and development of some typical black cotton soils and of Delhi Soils.
2. Electrochemical properties of organic colloid constituent of soil.
3. Interaction of clay minerals with micronutrient elements.
4. Cation exchange in homoionic and heterionic clays.

VII. Soil Survey.

1. Studies on formation of Kankars in Indian soils.
2. Soil survey of Delhi Farms and adjoining areas.
3. Soil survey in selected areas of Jaipur State and Central Province.
4. Soil survey of Karnal Farm and of Rann of Cutch.
5. Basic land resource areas.
6. Mineralogical studies of Indian soils.

VIII. Organic and Plant Chemistry.

1. Plant and synthetic insecticides.
2. Higher oil yielding linseeds.
3. Analysis of Oils and Fats.

IX. Microbiology.

1. Utilisation of indigenous phosphates through legumes for N-fixation.
2. Effect of application of phosphate at different stages of growth of legumes on N-fixation and yield.
3. Manurial value of sannhemp seeds.
4. Study of Azotobacter species of different soils.
5. Study of root nodule organisms.
6. Study of the methods of preserving palmyra juice.
7. Nitrogen fixation scheme. Study of the root nodule organisms of rahar and gram of different strains for N-fixation.

X. Biochemistry.

1. Nutritive value of legumes and grasses.
2. Mechanism of nitrification in the soil by soil percolation technique.
3. Estimation of Riboflavin by microbiological method (in samples of wheat-permanent manurial experiment, Pusa).
4. Estimation of Vitamin C, Carotene, Vitamin B complex in tomatoes, ladies finger etc., (seasonal).
5. Estimation of nicotinic acid by chemical methods (in wheat from permanent manurial experiment, Pusa).
6. Estimation of Vitamin B by biological methods (in wheat from permanent manurial experiment, Pusa).

XI. Physics.

1. Comparison of the estimation of B and Mn by spectrographic and chemical methods.
2. Zn, Co. and Mo estimation by the direct current arc method.
3. Deficiency problems in plants with reference to B and Mn deficiencies.

REPORT OF THE DIVISION OF ENTOMOLOGY

PARASITOLOGY

(A) Fundamental studies on insect parasitism.

(1) *Effect of monosaccharides (glucose and fructose) and disaccharides sucrose and maltose) diet on the longevity and fecundity of the egg-parasite, Trichogramma evanescens minutum Riley.*

Experiments carried out in the laboratory showed that tap or distilled water did not help in increasing either the longevity or the fecundity of *Trichogramma evanescens minutum* Riley as compared to no food. The longevity and the fecundity of the parasites were, however, significantly increased when fed with 10 percent solution of glucose, fructose, maltose and sucrose as compared to no food. The longevity and fecundity of the parasites had also increased to a considerable extent with a 10 per cent solution of yeast extract, *Corcyra* egg extract or centrifuged milk given to the parasites for feeding along with a 10 percent solution of glucose in equal proportions. Thus, whereas the maximum longevity of the unmated parasites, males or females, has never been more than 58 hours without food, the maximum longevity of those fed with 10 percent solution of the different sugars either alone or in combination with the various proteins has been about 3 to 5 times more in the case of males and 5 to 8 times more in the case of females. Similarly the maximum longevity of the mated parasites has been increased to about 5 to 7 times in the case of males and 7 to 9 times in the case of females when fed with the different sugars as compared to no food. The maximum longevity of the females, laying eggs in the presence of host, was likewise increased to 4 to 7 times when fed with these sugars as compared to no food.

(2) *Effect of low temperature on the viability, longevity, fecundity and sex-ratio of Trichogramma evanescens minutum.*

Observations made so far have shown that parasitised eggs of *Corcyra cephalonica*, 4 days after parasitisation kept at a temperature of 10-12°C. for 5 days gave on emergence (72-80 per cent.) a sex-ratio of 38 females and 62 males. The average longevity of the unmated females bred under similar conditions and without food and not laying eggs, was 38-hours while that of males under the same conditions was 29 hours. The fecundity of the parasites under the above conditions was rather low and 36-48 eggs were found parasitised by a single female.

Parasitised *Corcyra* eggs which had been kept at 10-12°C. for 70 days failed to hatch out at a temperature of 25°C. and 70 per cent relative humidity.

(3) *The ecology and biology of Bracon gelechiae, a larval parasite of the potato tuber moth, Gnorimoschema operculella.*

The longevity of mated females of *Bracon gelechiae*, without food and not ovipositing was 7, 8, 11, 11, 10 and 10 days at 25°C. and relative humidities of 40%, 50%, 60%, 70%, 80% and 90% respectively. The maximum number of eggs laid by a single unfed female at 25°C. and 80 percent relative humidity was 275 laid in the course of 25 days. At temperature 25°C. and relative humidities of 70% and 90% the number of eggs laid by an unfed female was 129 and 30 respectively.

At temperature 35°C. and relative humidities of 70%, 80% and 90% the longevity of the mated females was 7-9 days, 5-7 days and 4-6 days respectively.

(4) *Superparasitism in Bracon gelechiae*, an ectophagous larval parasite of the potato tuber moth, *Gnorimoschema operculella*.

In the course of experimental studies on the host selection by *Bracon gelechiae* it was observed that superparasitism had a direct bearing on (i) the size of individuals bred (ii) the number of adults bred per host and (iii) the sex-ratio of the resulting offsprings.

It was observed that where more than one parasite grub shared a single host, the size of the individual parasites decreased with the increase of the number of parasite grubs per host. Structural deformities and degenerated forms were also present in certain cases as a result of overcrowding and consequent insufficiency of food.

It was also observed that as the number of parasite grubs per single host increased, the number of males also increased. Or in other words when the food supply is insufficient more males are produced. The development period of the parasites is also increased with the increase in the number of the parasite grubs sharing a single host. (*Current Science*, 17, 1948).

(5) *Ecology and biology of Stenobracon deesae*, a larval parasite of the sugarcane top-borer, root-borer and stem-borer and the maize-borer, *Chilo zonellus*.

Observations on parasites bred on the natural host, *Chilo zonellus*, showed that at 25°C. and 70 per cent relative humidity, (a) the longevity of ovipositing females, fed with glucose solution, was 56 days, (b) the fecundity of a female under the above conditions was 54 (c) the pre-oviposition and post-oviposition periods were 5 and 12 days respectively, (d) 1-4 eggs were laid every day by a female and most of the eggs were invariably laid within 15 days after emergence.

Observations on parasites bred on the laboratory host, *Corcyra cephalonica* showed that at 25°C and 70 per cent relative humidity, (a) the longevity of the mated ovipositing females, fed with glucose solution was 42 days, (b) the fecundity of a female under the above conditions was 34 (c) the pre-oviposition and post-oviposition periods were 3 and 2 days respectively, (d) 1-3 eggs were laid every day by a female and the egg laying was continued for 31 days. These observations are of interest from the point of view of the mass breeding of the parasite in the laboratory.

(6) *Studies on Superparasitism in Stenobracon deesae*.

Under laboratory conditions more than one egg is laid on a host larva, but only one grub invariably reaches maturity. In nature also usually only one parasite develops out of one host larva.

In the case of some of the insect parasites, the grub that hatches out first, while feeding, releases certain toxins into the body fluid of the host, which is found detrimental to the grubs which feed subsequently. Experiments carried out in the laboratory have shown that no such toxin is produced in the case of *Stenobracon*. Cannibalism appears to be the main cause for the solitary nature of the parasite.

(7) *Influence of hosts upon their insect parasites.*

(a) *The effect of alternate hosts on the parasite, Bracon gelechiae*:—Experimental studies have shown that the effect of the hosts on the size of their parasites was the most striking influence. It was observed that the progeny of the parasite varied in size according to the species of the host on which they were reared; the smallest of individuals were reared from the small host (*Gnorimoschema operculella*) and the largest of individuals from the big host (*Scirpophaga nivella*). The hosts also influenced the size and proportion of the parts, the presence or absence of wings and the behaviour of adult parasites.

(b) *The effect of host on the parasite, Stenobracon deesae*:—In the case of *Stenobracon* also the most striking influence was the size of individuals bred. Parasites bred on the alternate host, *Corcyra cephalonica* were small and the percentage of males was rather high, while those bred on the natural host (*Chilo zonellus*) was normal in size and the percentage of males was comparatively less.

(B) Biological Control of Sugarcane Pests.

Trichogramma colonisation field experiments at Cuttack (Orissa):—To start with, the egg parasitisation of the stem borer, *Argyria sticticrasis* in the experimental blocks was 6.97 per cent and in the control blocks 5.55 per cent. During June to August the parasitisation ranged between 22.7 per cent and 80 per cent in the experimental blocks as against 3.6 per cent and 13.9 per cent in the controls. Later on 100 percent parasitisation was observed in the experimental plots in most of the series of observations against a maximum of only 39.3 per cent in the control and this shows that parasite liberations are very much effective in increasing the parasitisation in the field.

Before starting the release, *Argyria sticticrasis* damaged 4.7%, 4.55% and 4.75% of the shoots in 6 liberations, 12 liberations and control blocks respectively. In the experimental blocks the peak of damage by the borer was reached during April, May and June, and 9.5%, 10.6%, 11.9% and 15% of the shoots were damaged in the experimental blocks. In most of the control blocks the peak was reached by about the end of May, the pest damaging 16.6%, 15%, 18% and 18.2% of shoots. At the time of harvest 17.3% and 12.2% of the shoots in the six liberations and 12 liberations blocks respectively were found damaged as against 27.22 per cent in the control. The borer population per acre at the time of harvest was 250, 136 and 630 in the six liberation, 12 liberation and control blocks respectively. The average yield of cane in the six liberation, 12 liberation and control blocks was 835, 883 and 616 maunds per acre respectively. The pre-history of the experimental and control blocks being the same this increase in yield in the experimental blocks can be attributed, to a certain extent, to the efficacy of the parasite.

The Sugarcane Entomologist, Cuttack, again reports, "There is a growing demand from the general cultivators to release *Trichogramma* parasites in their fields to check the borer attack."

(C) Mass multiplication of beneficial parasites.

(1) *Bracon* (= *Microbracon*) *gelechiae*, a larval parasite of the potato tuber moth, *Gnorimoschema operculella* was bred in thousands per month as per requirements.

(2) *Trichogramma evanescens minutum* :—During the year under report 30,8919 *Corcyra* moths, 1147.5 c.c. of *Coreyra* eggs and about 15 million *Trichogramma* parasites were produced in the parasite laboratory.

SYSTEMATIC ENTOMOLOGY

Morphology of the external genitalia of Bruchidae and its taxonomical importance :—It is well known that the mouth parts and other purely external characters play an important role in fixing the inter-relationship between the various orders, families, genera and even between the species of the same genus; yet, the remarkable influence of identical ecological conditions and similarity in the bionomics of insect groups widely separated from each other in natural order, on such morphological characters need no special emphasis. In fact, examples of such convergence of morphological conditions are not uncommon in nature and, in cases like this, the diagnostic factors for speciation based on simple external characters, is liable to err. On the other hand, if the study of other morphological characters are further supplemented by a comparative study of less variable characters such as the various components of the genitalia, specially of the males of the forms concerned, the conclusion thus reached is likely to give a clearer picture of the inter-relationship that exists between the different forms.

In Bruchidae, in general, the distribution of coloured pubescent patches on elytron along with a few other external characters on which the present classification of this groups is based, seem to be so variable in the same species with different geographical distribution or bred from different hosts, that absolute reliance cannot be placed on these. It was, therefore, thought necessary to fall back upon some more reliable characters for this purpose.

The components of the female external genitalia of the Bruchids although simpler and comparatively less reliable factors in classification as compared to the male genitalia, they furnish additional features in fixing the systematic position of a form. Zacher proposed to base his taxonomic diagnoses on the number of ovarioles in a species, the structure of the spermatheca, the length of the accessory gland and duct of the spermatheca and the mode of termination of accessory gland and spermathecal duct into the spermatheca. But as most of these structures are present only in fresh forms to which a systematist has seldom access to on a large scale, and moreover, in fine dissections such as tracing out accessory glands and spermathecal ducts, one's success in cent percent cases is extremely limited. It was, therefore, thought necessary to base the classificator factors for Bruchids on such characters as are discernible without much difficulty from dried or preserved specimens. In female, these differentiating characters are the structures of the Bursa-copulatrix and the spermatheca. The Bursa-copulatrix having been studied for the first time in this Division for the purpose of classifying the Bruchids. (*Current Science*, July, 1949).

In the male genitalia, the differentiating characters have been traced in the structures of the Phallobase, the Exophallus, the Parameres and the different types of armature present on the Endophallus.

The following genera and species so far have been studied :—

1. Genus *Bruchus* :

Bruchus (= *Callosobruchus*) *chinensis* L.

B. Analis F.

B. phaseoli Gyll.

- B. Theobromae* L.
- B. pisorum* L.
- B. minutissimus* Motsch.
- B. vectabilis* Gyll.

II. Genus *Spermophagus* :

- Spermophagus convolvuli* Thumb.
- S. albofasciatus* Gyll.

III. Genus *Pachymerus* :

- Pachymerus gonager* F.

ECOLOGY AND TOXICOLOGY

(A) A new section of Insect Ecology has been established in the Division this year. Arrangements have been in progress for starting investigation on a number of ecological problems. The following items have received attention during the year.

1. *Epidemiology of cotton bollworms* :—This year the bioclimatic data on the population fluctuation of the spotted bollworm of cotton collected during the past six years have been under study. Taking the last six years average of weekly data as normal, weekly percentage deviations from the normal have been calculated for the six years and graphical correlation has been worked out between the weekly percentage deviations from the normal in the population per acre of (a) *Earias fabia* (b) *Earias insulana* (c) *Platydra gossypiella* and (d) parasites of these bollworms on the one hand and the weekly percentage deviations from the normal in (a) average temperature; and (b) average humidity on the other. These correlations are to be tried for predicting the population level of these pests in advance.

2. *Development of Corcyra cephalonica and Trichogramma evanescens minutum at different constant temperature* :—Rearing of *Trichogramma evanescens minutum* and *Corcyra cephalonica* for the purpose of making biometers for these two insects was in progress during the year at five constant temperatures and at 75 percent constant relative humidity.

Observations made so far showed that 59 to 62 days, 9 to 11 days, 6 to 8 days and 6 to 8 days were taken by the *Trichogramma* parasites to emerge at temperatures of 10°C., 25°C., 33°C. and 35°C. respectively. The parasites failed to emerge at 40°C.

In the case of the host insect, *Corcyra cephalonica* it was observed that this insect failed to develop at temperatures of 10°C. and 40°C. showing thereby that probably these temperatures were beyond the lower and upper limits of viability of *Corcyra* eggs. About 56 to 96 days, 33 to 56 days and a minimum of 55 days were taken by the *Corcyra* moths to emerge at temperatures of 25°C., 33°C. and 35°C. respectively. The moths are still emerging at 35°C. These results when confirmed will afford data for making Biometers for these two species.

(B) Fundamental investigations on Insect Toxicology were taken up for the first time in this Institute in the end of last year. The following problems have been under investigation.

1. *The correlation between specific susceptibility of insects to HCN and the amount of HCN recovered from the insects after fumigation* :—This problem was studied with larvae of *Corcyra cephalonica*, adults of *Tribolium*

castaneum, four different stages of nymphs of *Drosicha* sp. and adult females of the same *Drosicha* sp. The existence of a positive correlation between the above mentioned factors as reported by previous workers with other test insects was partially corroborated. Further, the following new fact was brought out : At first these species were given equal exposures to the same concentrations of HCN under similar conditions. The percentage mortality varied from species to species and from stage to stage of the same species and the insects could be placed in the following ascending order of their susceptibility : adults of *Drosicha* sp. *T. castaneum* adults larvæ of *C. cephalonica*, 3rd and 4th instar nymphs of *Drosicha* sp. 1st and 2nd stage nymphs of *Drosicha* sp. Subsequently the data were replotted with the amount of HCN recovered per gram body weight as abscissa and percentage mortality as ordinate. Quite surprisingly it was found that the above mentioned order of susceptibility was more or less reversed. The adult females of *Drosicha* sp. which appeared to be least susceptible by the ordinary criterion turned out to be most susceptible in this new way of analysis. As a result of these studies it has been concluded that the total effective resistance of different species shown by mortality studies after exposure to different concentration of a fumigant has to be resolved into (a) surface resistance in the way of entry of the poison and (b) the actual internal resistance to the toxic effect of the poison. The utility of these results in the search for new insecticides is obvious.

2. *Effect of concentration on temperature co-efficient of DDT action* :— Recently it was reported from America that the temperature co-efficient of DDT action is positive at higher concentrations and negative at lower concentrations inferring thereby that at low concentrations DDT penetrates the arthropod cuticle more effectively at lower temperatures. At this Institute it has been shown that probably the temperature co-efficient of DDT penetration remains positive at all concentrations but its value is reduced with the decrease in concentration till it gets masked by the positive temperature co-efficient of insect resistance to the toxic effects of DDT which exhibits itself as negative temperature co-efficient of DDT action.

3. *Correlation between the metabolic activity and susceptibility of insects* :— Correlation between the metabolic activities of grubs of *Trogoderma granarium* Everts and adults of *Tribolium castaneum* Hbst. and their susceptibility to carbon disulphide, chlorosol and methyl bromide fumigation was studied. It was found that both these insects when either starved for 72 hours or when kept at low temperature ($60^{\circ} \pm 2^{\circ}\text{F}$), evolve much less carbon dioxide than the normally fed insects and those kept at higher temperature ($89^{\circ} \pm 3^{\circ}\text{F}$. and $82^{\circ} \pm 4^{\circ}\text{F}$). The grubs of *T. granaria* were found to be more resistant to the action of these fumigants when starved for 72 hours even if fumigated at higher temperature (91 — 101°F). The adults of *T. castaneum* on the other hand were found to be more resistant than control ones when starved for 48 hours and fumigated only at temperature upto 88°F . Beyond this temperature, the acquired resistance due to starvation declines. In the case of *T. castaneum* adults, the starvation for longer than 72 hours at 68° — 78°F . showed decrease in resistance of insects. The importance of these findings in proper interpretation of fumigation results is obvious.

4. *Effect of fumigation on viability of grain seeds* :— Seeds of wheat, barley, oats, maize, berseem, soya bean, lentil, gram, pea, bajra, arhar, urid and cowpea were fumigated with carbon disulphide, chlorosol (ethylene

dichloride and carbon tetrachloride 3 : 1 V|V) and methyl bromide at a dosage of 10 lbs., 30 lbs. and 2 lbs. per 1,000 cu. ft. respectively of free and commodity space (free and commodity space combined). In all these cases, the fumigation flask was $\frac{3}{4}$ th filled with the material, the exposure period was 24 hours and the temperature of fumigation was about 70°F. (room temperature). The moisture content of these seeds was about 10 percent. The fumigation produced no adverse effect on percentage germination as compared with the control. Some seeds were kept in an atmosphere of R.H. 75 percent for about a month before these were fumigated as before. In this case also some of the seeds which were tested for germination so far were found to be unaffected.

Insect vectors of virus diseases

(i) *Host-plants*:—*Solanum nigrum* (black night shade) was found to be a suitable host-plant for mass production of the white-fly *Bemisia tabaci* in the laboratory for virus transmission experiments.

(ii) *Survey of sucking types of insects*:—The tobacco capsid bug, *Engytatus tenuis* Reut. was observed on *Lagenaria vulgaris*, *Polanitia viscosa*, *Sesamum indica* and *Gynandropsis pentaphylla*. Transmission experiments performed with adults and nymphs of this bug gave negative results.

Studies on stored grain pests and their control

Aplastomorpha calandreae, a chalcid parasite was found parasitising both *Bruchus chinensis* and *Bruchus analis* grubs that are serious pests of stored pulses in our country. The biology of this species has been studied at a temperature ranging from 78° to 82°F. and 60—65 percent relative humidity. This is an ecto-parasite that feeds on the body contents of the host-grub. The larval period lasts from 6 to 7 days and the pupal period 7 to 8 days. The female lays on an average 98 eggs when fed with raisins. The pro-oviposition period lasts from 3 to 4 days. The sex ratio was found to be 46 percent females and 54 percent males.

Observations on Indian insects of economic importance.

Pests of crops:—A survey of pests of field crops was continued as in previous years and the following species were found to be common and causing damage to some of the more important crops, the percentage of attack being given in brackets. *Heliothis armigera* and *Plusia nigrisigna* on gram (3-5% of plants), *Rhopalosiphum pseudobrassicac* (80 %), *Athalia proxima* (9% of leaves) and *Bagrada oruciferarum* (15-25 % of plants) on brasicca; *Macrosiphum solidaginis* on safflower (42 % of plants); *Myzus persicae* on tobacco and tomato (70-75 % of plants); *Nysius inconspicuus* on tobacco capsules; *Chilo zonellus* on maize (22% of plants); *Laphygma exigua* on jowar and cowpea (78 % of plants); *Gryllus domesticus* (24 % of plants) on cotton seedlings and *Dacus cucurbitae* on cucurbits (6 %). The more important pests observed on potato crop in the field were *Empoasca devastans*, *Myzus persicae* (78 %), *Megacoelum angustatus*, *Aphis nerri*, *A. rumicis* (negligible), *Agrotis ypsilon*, *Eusarcocoris ventralis* and *Cirphis unipuncta* during the months November to March. In the absence of the potato crop, *E. devastans* was found on cotton and cowpea while *M. angustatus* was found on cowpea and bhindi.

Fruit pests:—Among the fruit pests observed were the following *Aonidiella citrina*, *Myloceus laetivirens* on loquat, peach apple, plum and phalsa

foliage ; *M. 11-pustulatus* on apple and plum foliage ; *M. discolor* on citrus apple and ber foliage ; *Cryptocephalus bisexsignatus* on loquat, phalsa, apple, apricot ; *Phyllocnistis citrella* and *Pseudococcus corymbatus* on citrus leaves ; *Sphenoptera lafertei* on almond and peach stem ; *Adoretus lasiopygus* on grape vine ; *Luciola garhami* on *Zizyphus jujuba* ; *Oxyctonia versicolor* on phalsa, cucurbits and bhindi ; *Pagria* sp. on guava ; *Phycodes radiata* on fig ; *Strumeta cucurbitae* on cucurbit fruits ; *S. ferrugineus* and *Dacus ciliatus* on citrus foliage ; *Euproctis fraterna* and *Alcurocanthus woglumi* on citrus foliage ; *Drosicha stebbingi* on loquat, guava, pear, citrus and fig shoots and none of them appeared in a pest form.

Predators and parasites :—Among the predators observed were *Harpactor costalis*, *H. marginellus*, *Coranus* sp. and *Coryzus rubicundus* on the nymphs and adults of *Nysius inconspicuus*, a pest of tobacco capsules ; *Chilomenes sexmaculata*, *Coccinella septumpunctata* and *Chrysopa* sp. on *Aphis laburni* on cow-pea. The parasites, *Stenobracon deesae* on *Chilo zonellus* and *Microbracon* sp. on *Euproctis lunata* and *Marasmia trapezalis* were observed.

Studies on immature stages of insects

The following species were reared in the Insectary with a view to complete their life history studies and the plates illustrating the developmental stages of important pests of crops in India :—*Epilachna 28-punctata* on cucurbit ; *Acontia graelsi* and *Porthesia* sp. on cotton ; *Euproctis lunata*, *Ergotis merione* on castor ; *Utetheisa pulchella* on sunnhemp, *Marasmia trapezalis*, *Chilo zonellus*, *Porthesia xanthoria* on maize ; *Amsacta moorei* and *Sylepta derogata* on cotton ; *Laphygma exigua* on tomato, pea and gram ; *Sclepa* sp. on brinjal *Aerontia styx*, *Antigastra catalaunalis*, *Diacrisia* sp. on til ; *Plusia orichalcea* on berseem and potato ; and *P. nigrisigna* on gram.

PROGRAMME OF WORK FOR 1949-50

(1) INSECT TOXICOLOGY

Investigations on the following aspects will be continued :—

- (i) Correlation between specific susceptibility of insects to HCN and the amount of HCN recovered from the insects after fumigation.
- (ii) Effect of concentration on temperature coefficient of DDT action.
- (iii) Correlation between metabolic activity and susceptibility of insects.
- (iv) Effect of fumigation on viability of grain seeds.

(2) INSECT ECOLOGY AND EPIDEMIOLOGY

- (i) Epidemiology of cotton bollworms.
- (ii) Development of *Corecya cephalonica* and *Trichogramma evanescens minutum* at different constant temperatures.
- (iii) Aphid population on potato crop.
- (iv) Aerial insect fauna.

(3) INSECT TAXONOMY

- (i) Parasitic Hymenoptera.
- (ii) Isoptera.
- (iii) Coleoptera morphology of external genitalia of Bruchidae and its taxonomic significance.

(4) INSECT PARASITOLOGY

(a) Fundamental studies on insect parasitism.

- (i) Effect of monosaccharides and disaccharides diet on the longevity and fecundity of the egg-parasite, *Trichogramma evanescens minutum* Riley.
- (ii) Effect of low temperature on the viability, longevity, fecundity and sex-ratio of *Trichogramma evanescens minutum*, the egg-parasite of sugarcane stem-borer *Argyria sticticrasis* and *Microbarcon gelechiae*, larval parasite of the potato tuber-moth, *Gnorimoschema operculella*.
- (iii) Ecology and biology of *Bracon gelechiae*, a larval parasite of the potato tuber-moth, *Gnorimoschema operculella*.
- (iv) Ecology and biology of *Stenobracon deesae*, a larval parasite of sugarcane top-borer, root-borer and stem-borers and the maize-borer, *Chilo zonellus*.
- (v) Nutritional studies on the laboratory host, *Corcyra cephalonica*—relative nutritive value of different kinds of food.
- (vi) Influence of hosts upon their insect parasites—studies on the relationship between host physiology and the sex of the parasite.

(b) Biological control of sugarcane pests.

- (i) *Trichogramma* colonization field experiments at Cuttack (Orissa).
- (ii) *Pyrilla* parasite conservation experiments at Karnal.
- (iii) Control of *Pyrilla* by *Epipyrops melanoleuca* at Karnal.
- (iv) Field experiments on the control of top-borer, *Scirpophaga nivella* by *Telenomus beneficiens*.
- (v) Mass breeding of the host, *Corcyra* and the parasite, *Trichogramma evanescens minutum*.
- (vi) Possibilities of mass multiplication of *Stenobracon* and other potential parasites.

(c) Biological control of Potato tuber-moth, *Gnorimoschema operculella*.

(5) INSECT VECTORS OF VIRUS DISEASES :

- (i) Host-plants.
- (ii) Survey of sucking types of insects.
- (iii) Correlation between the heights of tobacco plants and the types of leaf-curl virus affecting them in the field.

(6) GENERAL BIOLOGY :

- (i) Studies on stored grain pests.
 - (ii) Observations on Indian insects of economic importance.
 - (a) Pests of crops.
 - (b) Fruit pests.
 - (c) Insect pests of potatoes.
 - (d) Insect pests of sugarcane and their natural enemies.
 - (e) Predators and parasites.
 - (iii) Studies on immature stages of insects.
- (7) Factors responsible for the development of alate aphids.

REPORT OF THE DIVISION OF MYCOLOGY AND PLANT PATHOLOGY

PLANT PATHOLOGY

1. Wheat.

Loose Smut (Ustilago tritici (Pers.) Jensen) :—Investigations on the Loose Smut of wheat have been conducted in cooperation with the Division of Botany. In all, a population of 390 varieties have been tested since 1945 against the three isolates either separately or in mixtures. Out of this number as many as 207 were tested in 1948-49. Eighty-one varieties of wheat, which were inoculated with isolates L_1 and L_2 with a view to test their resistance to Loose Smut last year, were planted this year and the following results were obtained. With isolate L_1 , sixty-seven varieties did not take infection, 10 showed infection up to 10 per cent. and 4 above 10 per cent., while with isolate L_2 , 58 varieties did not take infection, eighteen showed infection up to 10 per cent. and 5 above 10 per cent. One hundred and twentysix varieties of wheat which were inoculated with mixture of L_1 and L_2 showed that 99 varieties did not take infection, 17 were infected up to 10 per cent. and 10 above 10 per cent.; while with L_1 , out of the 126 varieties inoculated 88 did not take infection, 24 showed infection up to 10 per cent. and 14 above 10 per cent. During the year under report 225 varieties of wheat were inoculated with a mixture of isolates L_1 and L_2 , and 219 varieties with isolate L_1 with a view to test their resistance to the disease.

At Hoshangabad, 43 C.P. varieties which were inoculated with a local collection of *Ustilago tritici* last season showed that 31 varieties did not take infection, 8 varieties showed an infection up to 10 per cent. and 4 over 10 per cent. During the year under report 74 C.P. varieties were inoculated with a local collection for testing their resistance.

Physiologic races :—Eight isolates of loose smut which were sent to Canada have been shown to comprise at least three physiologic races by Dr. Hanna. As the differentials used in Canada do not seed under Indian conditions, fourteen varieties of wheat were selected from five species of *Triticum* for this purpose. The differential varieties were inoculated with isolates L_1 , L_2 , L_3 , L_4 , L_6 , L_7 , L_8 and L_{10} at Delhi. In addition, the inoculations have been carried out with these isolates at Kufri where isolates A_4 , A_5 , A_8 , A_9 and A_{10} have also been included in the test.

Karnal Bunt of Wheat (Neovossia indica (Mitra) Mundk.) :—One thousand two hundred and seven ears of 6 susceptible varieties of wheat were either inoculated at different stages with viable spores of bunt or were raised from inoculated seeds and seedlings. Tests were carried out in the field and also in sterilized soil in pots. The inoculation experiments were, however, unsuccessful probably because of unfavourable weather conditions. There was also no natural bunt infection during the year under report at Delhi. Inoculations on the same lines have also been done at Kufri.

2. Leafspot of Oats (*Helminthosporium avenae* Eid) :—

In 1947-48, *H. avenae* was found to occur in an epiphytotic form in the area of this Institute. In the 'Primary phase' of the disease, the blighted seedlings are either killed before or shortly after emergence, or show severe striping of the first or second leaves. Such seedlings succumb during their early stages of development or, if they survive, produce plants of impaired vigour. The 'Secondary phase' generally takes the form of leaf spot and ultimately leads to the infection of the seed.

It has been observed that primary infection increases with fall in temperature and early sown plants show lower infection as compared to the late sown. The incidence of the primary infection is greater in 25 per cent. soil moisture than in 50 per cent. The optimum temperature for growth has been found to lie between 18-24°C at pH 6.0.

Phalaris minor and *Avena fatua* have been found to be collateral hosts; also, self-sown plants of oats have been found to harbour the disease during the period from August—October. When oat varieties Victoria, Jannette, Richland, Minrus, Victory, N.P.1 and N.P.2 were tested, only Victoria was found to be highly resistant. Treatment with Agrosan GN successfully controlled primary infection.

3. *Lentil Wilt* (*Fusarium* sp.):—Field observations show that the disease occurs during the months of November, February to April whereas it is at its optimum in March. The disease is characterized by wilting, stunting, discolouration of roots and clogging of vessels by gummy substances. The disease has been successfully reproduced by a species of *Fusarium orthoceras* App. et Wr. isolated from diseased plants. The causal organism grows best at temperature ranging from 27—30°C and at pH 5.0. The tests conducted in glass columns showed that the fungus grows faster on sand than on soil.

Temperature varying from 23 to 31°C have been found to favour the development of the disease. The effect of soil moisture on the development of the disease was studied in specially designed metallic pots; maximum disease was observed in pots maintained at 25 per cent. of the water holding capacity. At full saturation the disease failed to develop.

Also, disease incidence was higher in the lots where plants had been raised either in sand or in mixture of sand and soil as compared to that in soil alone.

4. *Gram Wilt* (*Fusarium orthoceras* App. et Wr.):—Isolations made from large number of wilted gram plants yielded species of *Fusarium*, *Rhizoctonia solani* and *Operculella*. Symptoms produced on the plants harbouring these fungi were recorded but inoculation experiments conducted in pots with *F. orthoceras* produced typical wilt, thus confirming the previous findings. Reference will be found in the report of the Division of Chemistry to other investigations on gram wilt. The incidence of disease in different experiments in the Agronomy and Chemistry Divisions was recorded.

5. *Sugarcane* (*Saccharum officinarum* L.).

(a) *Red rot* (*Colletotrichum falcatum* Went):—It was evident from the Red Rot epidemic of 1938-39 that unless a variety possesses a fair amount of resistance to Red Rot it is not safe for extensive cultivation. Two hundred and six important commercial cane varieties have, therefore, been tested since 1936 in order to select resistant varieties suitable for cultivation. Also, a beginning was made in 1945 to test important cane varieties with a view to help the Sugarcane Breeder in selecting suitable parent material for evolving disease resistant varieties.

During the year 1948-49, one hundred and seven varieties, including *Saccharum spontaneum* collections, *Sclerostachya* etc., were tested for their resistance to red rot by the standard Plug method. In this connection about 4,500 canes were inoculated with a virulent strain of the causal organism. Out of 107 varieties tested 12 varieties, viz: *S. spontaneum* (Glagah, Java) *S. spontaneum* (Coimbatore), S. G. 851, Chunnee, Co. 301, 393, 408, 411, 413 440, 627 and 631, reacted as highly resistant; 25 as moderately resistant;

54 as moderately susceptible and the remaining 16 as susceptible. In the plug method of testing the cane rind is wounded and the inoculum is placed straight into the interior of the cane, thus doing away with the resistance that cane plant may have offered to the entry of the fungus into the cane. The fungus may spread rapidly within the cane once it reaches the interior tissue but may not be able to effect the entry easily. With this end in view since 1942-43 the relative resistance of a large number of cane varieties to red rot infection has been tested by nodal infection method. Certain varieties which had reacted as susceptible to linear spread of infection, once the red rot organism had gained entrance as in the plug method inoculations, showed considerable resistance to infection through the nodal region and may thus stand well in spite of red rot infection all about them in an epidemic tract. This method corresponds more to the natural mode of infection and may be reliably employed for testing field-resistance of cane varieties to red rot but to have an idea of true inherent resistance, which is essential for the selection of parent cane material for breeding red rot resistant varieties, the plug method is the only surest test. One hundred and two of the above mentioned varieties were tested for their resistance to red rot infection through the nodal region of the cane also. In this connection, about 2,500 canes were inoculated at the nodes. Considerable difference in the amount of infection was observed in the varieties tested. The percentage of infection varied from 0 to 60 in different varieties. Thirty-two varieties showed less than 5 per cent. infection and should be considered as highly resistant to this mode of red rot infection which chiefly occurs in nature; 16 varieties showed 5-15 per cent. infection; 25 showed 15-25 per cent. infection and the remaining 29 varieties which included Co. 213, 223, 312, 331, showed infection from 25-60 per cent.

(b) *Study of physiologic forms of the Red Rot Fungus* :—This work has been in progress since 1936 when it was realised that strains of the fungus differ from one another in their virulence. The severe Red Rot epidemic in Eastern U.P. and northern Bihar during the 1938-39 season further revealed the presence of a new strain in several hundreds of isolations, which was characterized by lighter colour and greater sporulation than the old strain. This new strain was found to be more virulent than the old dark type.

Since 1941-42 eighty-four *C. falcatum* isolates obtained from different places and different cane varieties have been tested for their virulence on ten selected cane varieties of varying genetic composition. During 1948-49 about 5,800 canes were inoculated with 29 isolates in connection with these tests. Judging by the linear spread of infection in the inoculated canes, great deal of differences in the virulence of various isolates tested have been observed. As before, light type, freely sporing isolates generally proved to be more virulent. The isolates also showed distinct differences in their power of nodal infection.

(c) *Smut (Ustilago scitaminea Syd)* :—Serious losses to sugarcane crop may result from smut infections if proper care of roguing and seed selection is not taken. Since such care is not exercised under average conditions of cultivation in this country, evolving smut resistant varieties is obviously the easiest and the cheapest method to control the disease. With a view to help the breeder in selecting suitable parent material, 205 varieties of sugarcane and other *Saccharum* spp. have been tested since 1936.

In 1948-49, of the 96 parent cane varieties tested for their resistance to sugarcane smut at Karnal, 53 showed less than 5 per cent. infection and may be regarded as highly resistant. These 53 varieties are : POJ 2725, 2727, 2878, 2961, *Striped Mauritius*, Q.116, G.1051, BH.IX, SG.63|32, Q.813, *Uba*, *Uba Marrot*, *Seleros achya*, SG. 201|1, *S. spontaneum* (Glagah Java), *Pansahi*, Co. 221, 244, 270, 281, 285, 352, 361, 370, 402, 407, 408, 412, 413, 415, 419, 440, 443, 449, 467, 469, 475, 513, 523, 527, 533, 534, 545, 615, 617, 627, 629, 630, 631, 636, 641, 653 and 654. Nineteen varieties showed 5-15 per cent. infection; 11 showed 15-25 per cent. infection and the remaining 13 showed 25-60 per cent. infection. In addition, 31 cane varieties, newly released by the Sugarcane Breeding Station, Coimbatore, were tested for their resistance to smut at Delhi. Of these, nine varieties, viz: Co. 631, 639, 641, 642, 643, 645, 653, 655 and 656 showed less than 5 per cent. infection and are regarded as highly resistant. Of the remaining 25 varieties, 11 showed 25-90 per cent. infection.

6. Linseed.

(a) *Rust* (*Melampsora lini* (Pers.) Lev.) :—The rust does much damage to the linseed crop causing a reduction in yield, breaking off of the stems at the point of attack and even the death of the plants. So far four physiologic races of the rust have been reported in India and varietal resistance tests were carried out on hybrids and crosses supplied by the Head of the Division of Botany. In continuation with the last years experiment 125 varieties of linseed were again tested for their resistance against rust both in the seedling and adult stages with mixtures of 4 physiologic races. Broadly speaking the results agree with those obtained last year and 70 varieties were found to be resistant to the disease. Sixteen varieties were semi-resistant as seedlings but resistant in the adult stage, 5 were semi-resistant both in the seedling and adult stages, 3 were susceptible as seedlings but semi-resistant in the adult stage and 31 varieties were found to be susceptible both in seedling and adult stages.

(b) *Wilt* :—The disease is known to cause considerable losses in the Punjab, U.P., and C.P. Observations on the incidence of the disease were made in the Institute area. A few plants were observed to wilt early in November but the disease again appeared in February and highest disease incidence was recorded during March. Two types of wilts were observed. One which occurs earlier is characterised by yellowing and withering of leaves, wilting, stunting and discolouration of the root system in part or whole. Fine hyaline hyphae are found in some of the vessels but these do not completely plug the vessels. A species of *Fusarium* has been found to be associated with this type of disease.

The other type of disease occurs late in the season and is also characterized by wilting of the plants. The discolouration in this case is darker brown in colour. The bark of the roots peels off and small sclerotia are found on the bark, wood of root and basal portions of the stem. Stout brown coloured hyphae occur in vessels. *Macrophomina phaseoli* (Maubl.) Ashby has been recovered from such plants.

7. *Clover rust* (*Uromyces trifolii* Hedw) :—The rust is very common on the cultivated clover *Trifolium resupinatum* and the crop at the farm of this Institute was found to be affected upto about 80 per cent. The rust is responsible for appreciable reduction in the leaf area thereby adversely effecting the fodder value of this important crop. The life-history of the rust

has been studied. The uredospores germinate within 2½ hours under favourable conditions. The optimum temperature for germination lies between 18-20°C. Infected material stored at 8°-10°C. was found to retain its viability for about 40 weeks whereas at 60°C the material lost its viability in 4 days. At 30°C. teleutospores were produced in place of second generation of uredospores which lost their viability in the summer heat. Inoculations made on 7 species of *Trifolium* resulted in the infection of only *Trifolium glomeratum*. The teleutospores collected in June only germinated in the following November and temperature between 15°-20°C. was found to be suitable. Freshly formed teleutospores, however, failed to germinate. Inoculations made with teleutospores resulted in the formation of pycnia and aecia after 9 and 12 days respectively. During the summer months, however, the inoculation tests were unsuccessful.

8. *Pea*—Wilt (*Fusarium orthoceras* App. & Wr. var. *pisi* Lind.) :—A serious wilt disease appeared in the pea field at the I.A.R.I. and the Agricultural Sub-Station, Karnal during the Rabi season 1948. The wilted plants showed recurving of the margin of leaflets, cessation of growth of terminal bud, yellowing and withering of lower leaves, spreading progressively upwards to the terminal bud. All the four isolates made from the material obtained from Delhi, Karnal, Naini and Chioki, agreed in morphological characters with *F. orthoceras* App. & Wr. var. *pisi* Lin. which is the agent of the common wilt of peas in other countries.

The wilt fungus shows optimum growth at 26°C and the incidence of disease has been found to be highest in sandy soils and at 60 per cent. soil moisture. A preliminary test indicates that addition of farm-yard manure in the soil may bring about reduction in disease incidence. The four isolates of causal organism differ in their physiologic characters as well as in their pathogenicity which has been tested on six different varieties of pea.

9. *Potato*.

(a) *Early Blight* (*Alternaria solani* (E. & M.) Jones and Grouet) :—The cultures of the fungus taken from potato plants showing distinctly different types of symptoms of the disease at Simla do not show any morphological differences. Plants inoculated at Delhi with either of the two cultures gave typical early blight symptoms. Four isolates of *Alternaria solani* from material obtained from different parts of the country were tested for their virulence on potato varieties *Phulwa*, *Gola* and *Darjeeling Red Round*. None of these varieties proved resistant to all the 4 isolates of the fungus. The isolate obtained from Delhi material proved to be virulent on plants of *Gola* and *Phulwa* varieties. Preliminary tests to determine whether Early Blight infection is carried by the tubers gave negative results. In this connection potato tubers of variety *Up-to-date* and *Darjeeling Red Round* harvested from heavily infected plants and those from healthy plants mixed with infected debris were planted in pots. Also healthy tubers of *Phulwa* variety were inoculated with cultures of *Alternaria solani* on the eyes and planted in pots.

(b) *Storage Rot* :—Twentyone varieties of potato were tested for their resistance to storage rot fungi *Fusarium solani*, *Rhizoctonia bataticola* and *Rhizoctonia solani* individually and in mixtures. Culture 301 appeared to be resistant to all the fungi. Hybrid 10 proved to be resistant to the individual fungi but when inoculated with mixture of the 3 fungi, showed infection percent. 33.3. Varieties S 80 and Na 86 which appeared to be resistant during 1945-46 proved susceptible in the tests during the year under report.

11. *Tomato—Damping off* (*Pythium deBaryanum* Hesse):—During August, 1948 considerable number of tomato seedlings showed damping off in the seedbeds. From the infected seedlings (*Pythium deBaryanum* Hesse) was isolated. The optimum temperature for growth of the fungus was found to lie between 27°-29°C. Experiments conducted with a view to control damping off have shown that the disease can be appreciably controlled by steeping the seed in 10 per cent. copper sulphate solution for $\frac{1}{2}$ -1 hour and disinfecting the soil with formaldehyde.

12. *Pigeonpea—Wilt* (*Fusarium udum* Butler):—Since 1945, 91 varieties of pigeonpea supplied by the Division of Botany have been tested for their resistance to the wilt disease. Out of 19 varieties tested for their resistance to the disease during the year under report, 5 varieties N.P. 41, Co. 15 W. Exp., Very Early, C.38-3-1 and N.P. 69 x U.P. 132—f.4-18B appear to be resistant. The disease incidence in general in the pigeonpea plots was rather low and the disease appeared late in the season.

13. *Antibiosis* :—As reported previously the percentage of infection by *Fusarium udum* the causal agent of pigeonpea wilt in the sterilized soil was much greater than in the unsterilized soil. Suppression of activity of *Fusarium udum* in unsterilized soils has been explained on the basis of the activity of the associated microflora, particularly two isolates of bacteria which have been identified to belong to *Bacillus subtilis* group. Relative colonisation of straw of the soil fungi and bacteria during the growth period of pigeonpea plants shows considerable variation. This is noteworthy in view of the fact that it indicates likely correlation between abundance of some of the organisms and the reduction in the incidence of pigeonpea wilt disease. The reduction of *Aspergillus terreus*, *Aspergillus niger* and *B. subtilis* during the month of November and their subsequent low level till the end of the cropping season corresponds to the high incidence of disease from November to February. Of all the micro-organisms isolated *B. subtilis* appears to be mainly responsible for inhibition of *F. udum*. The culture filtrates of some of the fungi though did not show any inhibitory effect on *F. udum* in artificial media yet their possibility of producing inhibitory substances under nutritional and environmental conditions prevailing in the soil cannot be obviated. The inhibition has been shown to be due to the metabolic products of the bacteria concerned and not due to any change in reaction of the medium.

Inhibition of germination of *F. udum* spores and subsequent abnormal morphological changes in the germ tubes serve as an indicator of the antibiotic substance. The toxic principle which is thermostable is partly held back by L₃ Chamberland candles. Importance of manganese, magnesium and iron in the production of antibiotic substance has been shown, while zinc in the presence of iron appears to retard its production. A medium for the optimum production of the antibiotic substance has been developed. Antibiotic substance produced in the soil maize medium inhibits the growth of *F. udum* in the soil columns. Such inhibitory effect, however, is less lasting in soil than in sand columns. An attempt has been made to study the interaction of the bacteria and *F. udum* by Cholodny technique in the pots.

14. *Fungicides* :—During the 'kharif' season of 1948 experiments were conducted to test the relative effectiveness of Ceresan, Agrosan-GN, Barbak, Spargon, copper carbonate and sulphur on germination and yield of maize variety yellow No. 2. Also their effectiveness on germination of jowar 'purbi' variety and bajra local variety was tested. Germination tests were

made in the window boxes in the laboratory. In the case of maize, seed treated with Ceresan, Agrosan GN and Spergon gave increased germination by 10, 9 and 5 per cent. respectively, whereas treatment of *jowar* and *bajra* seed with Agrosan GN gave increased germination of 16 and 15 per cent. respectively. Yield percentage increased in maize calculated on the basis of cob-weight was 13.5 with Agrosan GN.

During 1948-49 'rabi' season, fungicidal seed dressing trials were conducted with oat variety N.P. 1 and barley, variety NP 16. In these tests Ceresan, copper sulphate, Barbak, Aagrano and Agrosan GN were included. Oat seed treated with Ceresan gave 10.2 percent higher yield. Incidence of covered smut of oats was nil in the crop raised from inoculated seed treated with Ceresan, Aagrano and Agrosan GN, whereas in the untreated lot the disease incidence was as high as 17 per cent. Seed treatment of barley with Ceresan gave an increased yield of 8.5 per cent.

An experiment to test the efficacy of Dithane, Dithane+zinc sulphate + lime, Dithane + zinc sulphate + lime + D.D.T., Perenox (2 different doses), Burgundy Mixture, Burgundy mixture+D.D.T., and Parelane against late blight of potato was conducted at Kufri. The disease made its first appearance rather late in the season i.e. 3rd week of August. The disease assumed serious proportions by the end of the season and was responsible for serious losses of crop in the entire Simla Hills. The application of treatments stated above was started on 10th July and these were repeated at intervals of 10 days. It is noteworthy that due to continuous and heavy rains during August, six applications were actually given while it was drizzling or raining at the time of treatment or shortly after. Observations on the incidence of late blight and the percentage of leaf area destroyed by the disease were recorded for individual plants. Both Perenox and Burgundy mixture proved effective against potato late blight under conditions prevailing at Kufri but Dithane when used alone or with zinc sulphate and lime failed to provide any protection against the disease at Kufri.

15. *Assessment of Damage due to diseases* :—With a view to determine the economic importance of any disease and to have a clear conception of the susceptibility or resistance of a crop the losses due to the disease must be assessed. The subject has not received adequate attention with regard to conditions prevailing in India. Some experiments were laid out in this direction and are reported below. In the case of late blight of potato, observations on the incidence of the disease and the percentage of leaf area destroyed were recorded throughout the season. Ninetyfive to 100 per cent. infection of leaf area brought about a reduction of 50 per cent. in yield whereas 25-50 per cent. infection of the leaf area reduced the yield by 21 per cent.

An experiment was laid out to determine the effect of black rust on yield of wheat. Wheat varieties Agra local and N.P. 4 were sown in plots 15 ft. X 12 ft. each. Five plots of each variety were inoculated with black rust at heading stage and the other five were kept rust-free to serve as checks by frequent application of sulphur dust. In the inoculated plots as well as controls, farm-yard manure and irrigation were given uniformly and other agricultural practices were the same. It was found that the reduction in yield of Agra local wheat was 26.6 and 55.6 per cent. with 75 and 90 per cent. rust infection, respectively. In the case of N.P. 4, 20 and 38.7 per cent. reduction in yield was recorded for 50 and 90 per cent. infection, respectively.

Observations were recorded on previous year's ratoon sugarcane crop of Co. 312 with a view to assess the lossess due to sugarcane smut. It was

observed that the average weight of millable canes per smutted clump was 1.63 lbs. as against 2.64 lbs. for healthy clump. The average weight of millable cane per clump in the control plot was 2.25 lbs. The experiment in this connection was, however, spoiled by rats during the year under report.

16. Miscellaneous :

(a) *Mould counts in sweet potato flour* :—Mould counts of samples of sweet potato flour received from the Ministry of Food, Government of India, were taken up. Out of a number of media tested potato dextrose agar in the presence of sodium chloride was found to be most favourable for quantitative determination of *Aspergillus* and allied moulds, whereas acidified potato dextrose agar proved suitable for *Rhizopus* sp. The first sample examined gave a count of 1,440 colonies of *Aspergillus* and allied moulds and 320 colonies of *Rhizopus* per gram of flour. The total mould count per gram of the flour was 1760. In addition, *Fusarium* sp. and *Penicillium* sp. were also observed, but their proportion was 0.5 per cent. The second sample gave a total mould count of 1,350 but no *Rhizopus* colonies.

(b) *Study of airborne fungal spores* :—In order to forecast the outbreak of airborne fungal diseases particularly rusts and to study the seasonal variations in the fungal flora of air, glass slides smeared with vaseline were exposed in an aëroscope to catch fungal spores in the air about 3 feet above the ground. The slides were replaced by fresh ones every week and examined. Spores of *Alternaria* and *Helminthosporium* were commonly trapped. Spores of *Darluca*, *Diplodia* and *Abrothallus* were trapped during July. Spores of *Uromyces* were common during December. Viable uredospores of *Melampsora lini* and *Puccinia glumarum* were first trapped during the week ending 3-1-49. Uredospores of *P. glumarum*, *P. rubigo-vera* and *P. graminis* in a viable condition were trapped during the week ending 10-1-1949. This was followed by the outbreak of *P. glumarum* on the local wheat crop on 24-1-1949. During February to April rust and smut spores were common.

(c) *Cereal smuts* :—Germination tests were carried out with spores of loose smuts of wheat, oats and barley, grain smut of jowar and covered smuts of oats and barley that had been exposed to higher temperatures in the presence of moisture for a suitable period with the object of (1) finding out the temperature and the time of exposure that would kill these spores, and (2) subsequently finding out whether the solar treatment, with necessary modifications could be used to control the diseases.

Spores of loose smut of wheat, oat and barley and covered smut of oat exposed to temperatures ranging from 40°-50°C. for 4 hours in the presence of moistures showed that they lose their viability at 41°, 43°, 43°, and 45°C. respectively. Spores of covered smut of barley lost their viability when exposed to 45°-47°C. and spores of grain-smut of jowar when exposed to 49°-50°C. for a similar period.

(d) *Rust of Bajra (Puccinia penniseti Zimm.)* :—

Uredospores collected in October, 1948 and stored at 8°-10°C. remained viable for 24 weeks. Temperature between 10°-30°C. was found to be favourable for the germination of uredospores and germination of teleutospores was obtained between 10°-23°C.

(e) *Long Smut of Jowar (Tolyposporium Ehrenberghii (Kuhn) Pat)* :—Two hundred and twentyfour ears were inoculated with viable spores at different stages of floral development of the plants. Also the plants were raised from artificially infected seed with a view to check the aerial mode of transmission ascribed to the disease, but the results were negative.

PLANT VIRUSES

17. *Tomato (Lycopersicum esculentum* Mill.) :—

(a) *Leafcurl* :—The disease is characterised by stunting of the aerial organs, clearing of the veins, reduction in leaf-size and malformation and severe curling of the leaves. The affected plants become partially or completely sterile depending on the stage at which infection takes place, thereby causing serious losses to the crop.

The causal virus has been identified as *Nicotiana virus* 10. It has been indicated that the virulence of the virus may be reduced during passage through tomato plants. An experiment to test the effect of the activity of the virus after passage through other hosts such as *Datura stramonium*, *Capsicum annuum*, *Solanum nigrum* and *Amarantus viridis* was conducted. Severely affected tomato shoots were grafted on healthy stocks of these plants, and after the disease symptoms had appeared on these hosts, affected shoots from the new axillary growth of the stock were grafted back to healthy tomato plants. It was indicated that there is no change in the virulence of the virus after passage through *Datura stramonium*, while the virulence tends to fall after passage through *Capsicum annuum* and *Solanum nigrum*. The change in virulence of the virus appears to be of permanent nature since tomato shoots containing the attenuated and unattenuated virus, when grafted on healthy tomato plants, produced mild and severe symptoms respectively.

A preliminary test to determine if the juice of healthy leaves of *Solanum nigrum* has adverse effect on the activity of the virus, cut ends of severely affected tomato shoots were dipped in healthy leaf extract of *S. nigrum*. The scions were then grafted to healthy tomato plants. The control scions were kept in water for a similar period. It was observed that the grafts where scions had been previously treated with *S. nigrum* extract developed very mild symptoms of the disease, whereas new growth in the control grafts developed severe leafcurl, indicating thereby that the juice of *S. nigrum* has some adverse effect on the virus. Further work in this direction is, however, in progress.

(b) *Necrosis* :—Some plants of *Lycopersicum esculentum* variety Sutton's Early Market exhibited veinal necrosis and necrotic spots. The disease is readily transmissible by sap inoculation to *L. esculentum*, *Nicotiana tabacum*, *N. glauca*, *Datura stramonium*, *Solanum modiflorum* and *Petunia hybrida* variety *Rosy Morn*. Reactions on differential hosts indicated that the tomato plants showing necrosis were infected with a mixture of *Solanum Viruses* 1 and 2. Further tests with *Solanum Virus* 1 filtered through *D. stramonium* failed to reproduce typical symptoms of the disease. It was not found possible to eliminate *Solanum virus* 1 by passage through *P. hybrida* since the variety of *Petunia* plants available was found to be susceptible to it. This was, however, effected by passage through potato seedlings No. 41956. Inoculations with *Solanum Virus* 2, thus separated, failed to produce the disease on tomato. These tests show that either of the components of the virus transmissible to *D. stramonium* or to U.S.D.A. potato seedlings No. 41956 is not able to produce the disease on tomato independently, so that *Solanum viruses* 1 and 2 are jointly responsible for necrosis in tomato.

18. *Potato (Solanum tuberosum* Linn.) :—

(a) *Necrosis in potato, variety Tasmanian Bismark* :—Potato plants of *Bismark* variety grown in the glass-house exhibited stunting of the apical

shoots accompanied by downward curling of the leaf-tips and outward or inward curling of the margin of the leaflets. Later, distinct veinal and interveinal necrotic spots developed near the leaf-tip which later spread along the margins resulting in the drying up of the leaves. The disease is not sap inoculable but could be readily transmitted by grafting to potato variety *President*, *Datura stramonium*, *Lycopersicum esculentum* variety *Sutton's Early Market* and *Nicotiana tabacum* varieties *Harrison's* and *White Burley*. The virus is also transmissible by the agency of the whitefly, *Bemisia tabaci*, and produces typical leafcurl symptoms on tobacco varieties *Harrison's Special* and *White Burley*. The causal virus has been identified as *Nicotiana virus* 10.

(b) *Foliar necrosis in potato plants of Phulwa variety*.—Potato plants of *Phulwa* variety exhibited foliar necrosis, the chief symptoms being widespread multiple necrotic spotting followed by veinal necrosis. The disease is readily transmissible by sap inoculation to potato varieties *Phulwa*, *President* and *Up-to-date*, *Nicotiana tabacum*, *N. glutinosa*, tobacco variety *White Burley*, *Datura stramonium*, *Lycopersicum esculentum*, *Solanum nodiflorum*, *Capsicum annuum* and *Petunia* sp. The disease could not, however, be transmitted to plants belonging to a number of different families. The properties of the virus have been studied. The virus loses infectivity after 10 minutes exposure to 68°C and retains activity for 39-42, 19-21 and 7-8 days when stored at 0-2°C., 4-7°C., and 25-30°C. respectively. The virus in crude sap becomes innocuous at 1-5,000 to 1-10,000 dilution. The infectivity of the virus is unimpaired even after passage through Chamberland candles of grade L₃ and L₅ and the virus remains infective over a wide range of pH i.e., 2.9 to 7.4. Undiluted extract of the infected leaves is resistant to 60 per cent. alcohol, 2 per cent. formalin, 0.25 per cent. acetone, 0.1 per cent. mercuric chloride and hydrogen peroxide, 0.05 per cent. potassium permanganate as well as exposure to equal proportion of ether and chloroform for one hour. The virus in undiluted sap is inactivated by 70 per cent. alcohol, 3 per cent. formalin and phenol, 0.5 per cent. acetone, 0.25 per cent. mercuric chloride and hydrogen peroxide, 0.1 per cent., potassium permanganate, as well as by treating with equal proportion of glycerine. The virus has been identified as *Solanum virus* 6.

19. *Sannhemp (Crotalaria juncea Linn.)*.—

(a) *Mosaic*.—The virus is sap inoculable and can be readily transmitted to *Nicotiana tabacum*, *N. tabacum* var. *White Burley*, *N. glutinosa* and *Pisum sativum*. It has thermal death point of 68°-70°C., longevity *in vitro* of 71-76 days at 12-15°C, and in crude sap the virus can tolerate a dilution of 1 : 1,000 but is rendered innocuous at 1 : 5,000. The virus in standard extract is resistant to 0.5 per cent. potassium permanganate and 0.025 per cent. formalin but is rendered innocuous by 0.05 per cent. formalin and glycerine.

Some more material was crystallised by method suggested by Markham and Smith (1946) as also by Bawden's method already reported. Work on the determination of the vector was initiated.

(b) *Dwarfing*.—About 20 per cent. of the plants in the experimental area were found infected with the disease. The virus is sap transmissible and typical symptoms are produced after 12-15 days while in the presence of carborundum as an abradant the disease symptoms are produced after 7-10 days. The virus can infect *Nicotiana tabacum*, *N. tabacum* var. *White Burley* and *N. glutinosa* but not *Pisum sativum*. The virus has thermal death point of 85°-90°C., longevity *in vitro* for a period of 41-50 days at 12°-15°C. and in crude sap can withstand a dilution of 1 : 25,000—1 : 30,000.

20. *Bottlegourd* (*Lagenaria leucantha* (Duch.) Rusby):—

(a) *Mosaic* :—The properties of the virus causing a mosaic disease of bottlegourd have been studied in detail. The virus loses infectivity when exposed to 88°C. for 10 minutes, retains its infectivity for a period of more than 90 days and in pure sap becomes innocuous at 1 : 10,000 dilution. The activity of the virus is not impaired after passage through Fuller's earth. The virus has been found to be a new strain of *Cucumis virus* 2 and has been designated as *Cucumis virus* 2 C according to the classification by Smith and Marmor *strictum* var. *subobscureum* var. nov. according to the classification by Holmes. The age of maximum susceptibility of the host to the virus lies between 17-33 days while the pH infectivity range lies between 1.88 and 9.96. The pH stability, however, is dependent upon temperature and the period of storage. After 15 days storage at 7°C. the virus retains its activity at pH 2.28 to 9.6 while after storage for the same period at 18°-20°C. (room temperature) the virus is found to be infective at pH 3.04 to 9.96. The virus in standard extract is resistant to 1-2 per cent. nicotine sulphate (40 per cent.), 40 per cent. hydrogen peroxide, 0.25 per cent. mercuric chloride, 50 per cent. alcohol, glycerine and acetone and 0.5 per cent. potassium permanganate, silver nitrate and carbolic acid. The virus is inactivated when treated for 24 hours with 50 per cent. hydrogen peroxide, 1 per cent. potassium permanganate, silver nitrate and carbolic acid and 0.5 per cent. formalin while 2 per cent. potassium permanganate and 1 per cent. formalin render the virus innocuous in one hour. It was further observed that 50 per cent. nicotine sulphate (40 per cent.), 0.5 to 2 per cent. copper sulphate, 0.5 per cent. mercuric chloride and 2 per cent. formalin either inactivate the virus or affect the host susceptibility.

Preliminary observations were made on the effect of ultraviolet radiation on the activity of the virus. It was observed that the bottlegourd mosaic virus in standard extract is inactivated when exposed for two hours (171.36 minimal units of doses) to ultraviolet radiation. The effect of dilution on inactivation of bottlegourd mosaic virus was also tested and it was observed that undiluted virus in filtered sap is not inactivated even when exposed for a period of three hours (257.04 minimal units of doses) while at a dilution of 1 : 100 or more its infectivity is lost when exposed only for one hour (85.68 minimal units of doses).

(b) *Analysis of the factors underlying specialization of the host range of bottlegourd mosaic virus* :—The virus has been shown to possess a restricted host range and does not show any obvious symptoms on any of the Solanaceae tested. It has, however, been shown that the virus can establish itself on *Datura stramonium* plants which carry the disease symptomlessly. It has also been shown that the extract of *D. stramonium* markedly inhibits the activity of the virus and the infectivity of the virus is also adversely affected by prolonged storage of the virus with *D. stramonium* extract. The greater the storage period, more marked is the inhibitory effect. The extracts from old *Datura* plants show greater inhibition of the virus than the extracts from young plants. Also *D. stramonium* plants carry the disease for a limited period of their growth, but when they grow older there is no evidence of their carrying the disease, so that it is only the young plants on which the virus can establish and no evidence of this has been found on older plants.

Datura leaf extract shows inhibitory effect on the virus when mixed with it beyond certain proportions. The fact that the inhibitory effect is destroyed

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on heating indicates that some toxic principle is involved. The concentration of such principle in the mixture determines the inhibitory property of the extract. Evidently concentration of the toxic principle in young *Datura* plants is not high enough to inhibit the multiplication of the virus and as the plant grows old, the toxic principle in the leaves increases to a point beyond which it inactivates the virus and the plant ceases to be a carrier. The findings are of considerable interest chiefly because this is the first record of the virus infecting plants outside *Cucurbitaceae* and that the restriction of the host range of the virus as far as *D. stramonium* is concerned is due to the adverse effect of its sap.

22. Miscellaneous :—

(a) *Leafcurl of Hibiscus rosa-sinensis* :—Leaves of affected *Hibiscus rosa-sinensis* show faint mottling in early stages. The leaf-size is reduced and vein thickening is commonly observed. Later, enations develop on the veins on under-surface of the leaf. Puckering of leaf is a common feature of the disease and the margins of the severely affected leaf may be curled upwards. The disease is not sap-inoculable but is readily transmissible by grafting. The virus appears to have a wide host-range including bhindi and cotton.

(b) *Schizanthus* sp. as a host of *Nicotiana virus* 10 :—*Schizanthus* sp. was found affected by a disease which is responsible for bronzing of the apical leaves and downward curling and inward rolling of the leaves. The disease was successfully transmitted by *B. tabaci* and the virus identified as *Nicotiana virus* 10.

(c) *Leafcurl of Thevatia nerifolia* was observed commonly in Delhi, and was found to be graft-transmissible. Transmission tests with the sterility of pigeon-pea, mosaic of bean (*Dolichos lablab*) and vein-banding mosaic of chilli have proved virus nature of the diseases since in all these cases the disease could be successfully transmitted by grafting. Attempt to transmit these viruses by insects have so far given negative results.

22. *Seed Potato Certification Scheme* :—The potato crop at Fagu, Kufri and Simla Hill was examined at different stages of growth for disease incidence, *Up-to-date* variety is mostly distributed throughout Simla Hills. The incidence of severe types of virus diseases varied from 4.3 to 9.6 per cent. ; the incidence of negligible types of mosaic varied from 28.1 to 47.5 per cent.

Late blight disease was again observed in an epidemic form in the plains at Hapur in *Phulwa* and *Gola* varieties. In most of the fields of *Phulwa* variety the incidence of the disease was 100 per cent. resulting in serious losses in yield. The disease in *Phulwa* variety appears to have been carried over through seed tubers from last year's infected crop which had been stored in the cold store during the summer.

Selection and Multiplication of Virus-free material :—

Tubers of healthy plants of varieties *Darjeeling Red Round*, *Up-to-date* and *Majestic* and potato hybrids 2, 9 and 12 which were selected and raised at Central Seed Potato Certification Station, Kufri, during the last season were again planted during April-May 1948 at Kufri. Some material of *Up-to-date* and *Great Scot* varieties obtained from Potato Breeding Substation, Simla, was also planted during June 1948 for multiplication. In addition, *Arran Victory*, *President*, *Craig's Defiance* and Seedling No. 41956 were planted for multiplication work. The healthy material of *Darjeeling Red Round*,

Up-to-date and *Majestic* varieties was also multiplied by sprouts. The entire crop was examined at regular intervals and the undesirable plants were rogued out. The selected plants were harvested during September-October 1948. The selections raised at Kufri were grown in the insect proof house at Delhi and tested on differential hosts for freedom from virus diseases. All the material of variety *Great-Scot* and some of *Up-to-date* obtained from Simla Substation was found to be infected with virus diseases. The tested and selected material in general was planted at Kufri during April-May 1949 for further selection and multiplication. In addition to the area planted at the Seed Certification Station at Kufri 2 acres of land have been put under potato variety *Darjeeling Red Round* in cooperation with Patiala State for the multiplication of the healthy material of this variety. Rapid multiplication of disease-free material of *Up-to-date* and *Majestic* varieties was continued by means of sprouts, so that more than 500 plants of these varieties are now available at Kufri.

Selection of virus-free material of *Phulwa* variety was continued and, after tests in the glasshouse, four plants of this variety have been selected for further study.

In order to obtain disease-free nucleus of 36 promising hybrids preliminary selections were made in the crop grown at the Potato Breeding Substation at Simla during 1948. The tubers of the selected plants of these hybrids have been planted in hill units at the Central Seed Potato Certification Station, Kufri, for further selection.

SYSTEMATIC MYCOLOGY

23. *Taxonomy* :—Studies in the genus *Colletotrichum* were continued and a number of new hosts have been established. In addition, some of these appear to be new species. Also studies of miscellaneous specimens chiefly belonging to the genera *Septoria*, *Pleosphaeropsis*, *Glomerella*, *Valsella*, *Cercospora*, *Macrophomina* & *Fusicolla* were in progress. A number of new species and new hosts have been established.

24. *Indian Type Culture Collection of Fungi* :—During the year under review the Indian Type Culture Collection of Fungi of the Division of Mycology became a Member of the International Federation of Culture Collections. The Culture Collection of this Institute is also represented on the Indian National Committee on Type Cultures of micro-organisms and, through the latter body, is also a collaborating Member of the "Commonwealth Culture Collections of Micro-Organisms".

Fifty-three cultures were added to the Collection and the total number of cultures now exceeds 750. One hundred and twentyfour cultures were supplied to Research workers in India and abroad, and to Industrial concerns in the country.

The mineral oil preservation method was adopted to preserve a number of cultures. Tests to determine the suitability of this method for preserving other fungi are still in progress. The oils used in these tests were Nujol, BOC. 120 and commercial paraffin. The viability tests without the use of mineral oils were also conducted. It has been indicated that *Zygomycetes* generally remain viable in ordinary culture for more than 12 months.

25. *Herbarium (Crypt. Ind. Orient.)* :—Two hundred and eight specimens from the Collection were supplied to various research workers, and teaching

institutions both in India and foreign countries. The total number of specimens in the Herbarium is now 18,750, including 12 *Exsiccati* sets. Sixty new specimen of Indian fungi and bacterial diseases were added to the Herbarium, as also one *Exsiccati* (*Graminicolous* smuts of North America Century 1) and 2 fascicles of *Myriagiales Selecti Exsiccati*. In addition six hundred Mycological specimens including some common ones were collected, particularly for training purposes, during the year under report.

PROGRAMME OF WORK FOR 1949-50

1. *Plant Pathological Investigations* :—

- (a) Studies on the important cereal smuts.
- (b) Determination of Physiologic forms of *Ustilago tritici* (Pers.) Jensen and *Colletotrichum falcatum* Went.
- (c) Wilt disease of gram, pigeonpea, *til*, oilseed, lentil, etc., also disease of other economic crops.
- (d) Studies on rusts of wheat, linseed and gram.
- (e) Relative effect of fungicides on stand, emergence and yield of *Kharif* and *Rabi* crops in relation to disease incidence.
- (f) Assessment of damage due to plant diseases with particular reference to late blight of potato, Black Rust of wheat and sugarcane Smut. Aerobiological studies.
- (g) Varieties evolved by the Botany Division will be tested for their resistance to diseases.
- (h) Diseases of sugarcane—Varietal resistance to Redrot and Smut.
- (i) Studies on microbial antagonism.
- (j) Study of bacterial disease of wheat (*Phytomonas tritici*) and bacterial rot of vegetables and fruits.

2. *Plant viruses* :—

- (a) Virus diseases of *leguminosae*, *cucurbitaceae*, *Solanaceae*, etc. Also further study of sugarcane Mosaic Virus strains.
- (b) Properties of the purified preparation of sann-hemp Mosaic virus.
- (c) Study of insect vectors of the viruses.

3. *Mycological investigations* :—

- (a) Taxonomy of fungi with particular reference to unidentified collections available in the Herbarium Crypt. Ind. Orient. as well as new collections. Also that of genus *Colletotrichum* and study of fungi of Delhi.
- (b) Maintenance of the Indian Type Culture Collection of Fungi and investigations to evolve new methods for preservation of fungi.
- (c) Additions to and maintenance of the Herbarium.
- (d) Identifications of fungi and diseased specimens.

REPORT OF THE DIVISION OF AGRICULTURAL ENGINEERING.

RESEARCH PROJECTS.

Study of Low H.P. Tractors.—With a view to investigate the practical and economic possibilities of low horse-power tractors in this country, experiments were continued with a "Gravely Model L" tractor which is powered by a 5 H.P. air cooled engine and is of the walking type on two wheels, where a man steers the machine walking behind it. This tractor was tried in harvesting berseem crop, in operating a stationary thresher during 1947-48 and in ploughing using a rotary plough during the current year. It was found uneconomic and unpractical compared to riding tractors of higher H.P., as the walking tractor has a low speed of field operation and consequently high consumption of fuel per unit of work done apart from difficulties of operation under extreme climatic conditions. Walking tractors are also usually fitted with air cooled engines and as such are not suited for continuous operation in the open fields during the hot months. Also they are fitted with petrol engines, where the cost of operation is higher than for kerosene operated engines. As a result of the trials, it was found that walking tractors with air cooled petrol engines were unsuitable both economically and from a practical point of view under Indian conditions for arable farming. The following is a detailed report on tests conducted during the year under report.

In continuation of the trials carried out during 1947-48, tests of the rotary plough attachment were carried out in the I.A.R.I., between 13-10-48 to 21-10-48. The shade temperature during these trials ranged from 90°F to 94°F. The objects of the trials were to determine the practical and economic possibilities of such type tractors and in this instance to study generally the working of the rotary plough attachment.

As recommended by the manufacturers, SAE 40 lubricating oil was used and the engine fuel was standard marketed petrol. The trials were conducted in a sandy loam soil. Trials Nos. 1 and 2 were carried out in a field which was not cropped during the preceeding season and had a soil moisture content of 3.6 per cent. by weight. The rest of the trials were carried out in maize stubble field with a moisture content of 6.5 per cent. by weight.

Table No. I shows the results of experiments carried out.

TABLE I.
Low H.P. Tractor Trials.

Ser'l No.	Depth of ploughing	Petrol in gallons/hour	Acres/hour	Acres per gallon	Gallons per acre	Average working speed	Remarks.
1	3.5"	0.310	0.050	0.0160	6.25	..	Ploughing in high gear.
2	4.5"	0.310	0.020	0.064	15.50	..	
3	4.0"	0.430	0.053	0.130	7.80	..	
4	5.5"	0.470	0.045	0.096	10.50	..	Ploughing in low gear.
5	5.0"	0.430	0.060	0.135	7.50	1.9 m/h.	
6	5.0"	0.375	0.047	0.125	8.00	1.9 m/h.	
7	5.5"	0.310	0.050	0.160	6.250	1.9 m/h.	
8	..	0.375	..	..	..	..	

Note :—(1) *Petrol Consumption.*—Trial No. 8 was a no load test, carried out in a shade temperature of 85°F and gave a petrol consumption of 0.375 gallons per hour. In this

test the engine was running continuously. From the average of trials number 5 and 6, when the engine runs continuously under load, the petrol consumed was 0.40 gallons per hour.

- (2) *Acres per hour*.—Trials number 4 and 5 are dependable, as they were continuous in operation. Acre per hour ploughed in these trials averaged 0.052 and this agreeing closely with the results of trials number 6 and 7.
- (3) *Gallons per acre*.—From the results of trials number 4 and 5, petrol required for ploughing averaged 9 gallons per acre.

Conclusions.—In this operation of rotary ploughing the soil is pulverised and it is feared that in this condition, more moisture may be lost due to evaporation, than under turn ploughing and the possibility of soil erosion by wind or rain prevailing immediately subsequent to ploughing is a direct possibility. Although the full width of the rotary plough is approximately 13 in., the maximum width of ploughing that was reached was 6.15 in.

Except in the test under no load, which was conducted in the laboratory, the tractor did not continuously operate for more than one hour, due in all cases to engine trouble. This was due in the main to the inability of the needle valve to maintain a constant setting and the absence of a speed control device under varying load conditions i.e. a governor. Most of the stoppages occurred under a heavy load or under turning or manoeuvring bunds. When raised out of the ground to negotiate an obstacle the engine races and when put suddenly under load it stalls. Also at turning, when load is released its speed is more than 4 miles per hour even in low gear. In low gear and under load its average speed is 1.9 miles per hour. Thus whenever the operator is manoeuvring an obstacle, its speed so increases that operation becomes very exhausting. Thus the observations made in the first interim report regarding the suitability of this tractor for operation under Indian conditions are again borne out.

Possibilities of utilising suitable low H.P. Engines in lieu of bullocks for ploughing.—Two desi plough bottoms were suitably hitched behind a walking tractor and successfully used for ploughing operations. A suitable hitch for attaching 3 desi plough bottoms is now being designed together with a type of low horse power prime mover without the disabilities as outlined in the report above, on walking type tractors.

Compilation of Tractor data.—Comparative comprehensive operational costs and rates of performance of different makes of tractors both of the wheel type and track type, some operating on kerosene and some on Diesel fuel have been collected and data compiled. The data compiled here are confined to owner-operator conditions and not to farm operations conducted as a contract enterprise or under state ownership, where overhead charges and long distance hauling of the machines to places of operation have to be included. These figures do not apply to opening up of new lands or land reclamation work. They are a useful guide to individual cultivators who contemplate mechanised agriculture or a gradual change over from bullocks to tractors.

Mobile Power Unit.—There are many farm operations in mechanised agriculture, which need a stationary power unit, as for example pumping water, threshing grain, baling hay or processing of farm products. Most of the modern tractors are provided with a belt pulley, which can adapt the

tractor as a stationary power unit as well as for field operations. But generally stationary farm operations such as pumping or threshing require much less power than even a medium size tractor (13-16 H.P.) is designed to transmit on its belt pulley. It is well known, that engines operate at their maximum efficiency when they are loaded at $3/4$ to full of their rated power. During operations at less than the $3/4$ full load, the efficiency of operation of the Internal Combustion Engines drops rapidly with a resulting higher operating cost compared to the amount of work done.

To obviate this situation a diesel engine of 5-7 H.P. running at an average of 1500 R.P.M. was installed on a 4 wheeled structural frame work, which was entirely built of scrap material generally available in a workshop. This mobile power unit could be hauled anywhere in the farm by two bullocks. The unit was used during this season for operation of a small Danish Thresher details of which are given on another page. The unit proved economical and can be used for many stationary operations.

New Twin Country Plough.—In an original research project recently carried out by this Division to study the economic and practical possibilities of country plough operation by a low horse power tractor in lieu of bullocks it was discovered that the draught of two country ploughs suitably coupled together fell far short of double that required for a single plough and it was immediately decided upon to investigate the possibility of designing a double desi plough capable of being operated by a single average pair of bullocks.

The new plough as finally designed is simple in construction and consists of the bottoms of two standard local desi plough suitably coupled together by means of an angle iron frame work and pulled by a single central beam. The ploughs are so spaced in relation to each other that identical furrows are cut and carry out in one operation similar work as would be performed by two operations with a single standard plough.

The plough is comparatively light, its weight being 87 lbs. as against the 40 lbs. of a single desi plough ; thus an average ploughman can easily lift and carry it as required for ordinary operational purposes. The draft is, tolerable, being, in hard dry land, ploughing 5 in. deep, 254 lbs., while that of a single similar plough under similar conditions was 157 lbs. The draft of a single 'Victory', bullock drawn, soil inverting plough under average conditions varies between 320 and 400 lbs.

The merits of the plough are obvious. Bullocks, generally so far as ploughing is concerned are under-loaded, and based on observations made on bullocks when operating 'Victory' plough and single desi ploughs there is little doubt that this new ploughs is capable of being operated by single pair without undue extra effort. Assuming this, its daily output will be practically double. Taking an extreme where bullocks are capable of operating this plough for only half the usual daily working period the out-turn of work will be similar and the cultivator's extra time will be available for relaxation or alternative work. Quality or regularity of ploughing must automatically be improved. Seasoned ploughmen who have used the plough state that in operation it is easier and less tiresome to handle due to its 'stability' when in work. When in production it is estimated that its cost will not exceed Rs. 45/- when compared with the present cost of a single desi plough at Rs. 30/-; a feature of importance for it is the cultivator and not the landlord who has to purchase implements.

It is simple in construction and thus easily repaired or even constructed by the village blacksmith or carpenter and may well prove to be of great value in the effort being made today to increase food production, and at the same time easing and improving the work of the cultivator.

Utilization of rotted material from town refuse dump.—As a part of the compost development scheme of the Grow More Food Campaign, the rotary screen designed last year was the subject of further experiment and trial. The machine, as now finally designed has been fitted with a $1\frac{1}{2}$ H.P. petrol engine and the following performance figures were recorded during trials carried out at the instance of the Compost Development Officer, Ministry of Agriculture.

Total material fed at the hopper in maunds per hour 120 to 150

Maunds of finished material sieved and delivered

per hour 80 to 100

Total petrol consumption per hour in pints 1.00 to 1.50

Harvesting Machinery.—(i) A few small threshing machines were built several years ago entirely in steel by a firm in Muzaffarpur (Bihar) and this model is now being manufactured by a firm in Coimbatore. It can be run by a 5 to 6 H.P. motor or engine, but due to want of a winnowing attachment, the grain which is delivered from the machine, has to be passed subsequently through a winnowing machine or cleaned by hand. All models of foreign machines are now built in such a way that clean and graded grain is delivered from the machine. To improve the existing model, a fan was built in its frame work with other suitable structural modifications, so that threshing and cleaning of grain takes place in one operation. This machine is now awaiting trial.

(ii) a. Harvesting machines. Designs of the first working model of a small engine operated reaping machine suitable for harvesting standing grain in the field were completed. The machine is designed to cut about 4-5 acres of grain per day and is operated by one man and consumes 1.25 gallons of petrol for 8 hours. Some defects in the driving arrangement to the land wheels, in the original design are now being rectified and the machine will be subjected to further trial shortly.

b. On the principles of the power operated reaping machine mentioned above, three alternative models of hand operated reaping machines have been designed and constructed. They await further field trials.

(iii) Two threshing machines, claimed to be economical in operation on small holdings as generally prevalent in Europe were obtained from Denmark for purposes of trial. These two machines are designed for operation by electric motors or Internal Combustion Engines and are built mostly in wood. There are, however, ball and roller bearings in the construction. The machines can be hauled on the farm from place to place by two bullocks when placed on a light trolley on 4 wheels. The following are the brief specifications of the two machines :—

Specification of Danish Thresher No. 1

Overall dimensions	9'-9" long, 2'-0" wide & 5'-0" high.
Diameter of the drum (peg type)	14" & length 14 $\frac{1}{2}$ " mounted on 1 1/8" dia. shaft & running at 1400 R.P.M.
No. of pegs	20
Distance between the two pegs	3 $\frac{1}{2}$ "
No. of oscillation of the shakers per minute	220
Distance of throw	6"
Nos. of shakers	3

Specification of Danish Thresher No 2.

Overall dimensions	..	..	..	..	..	11'-9" long, 2'-9" wide & 6'-8" high.
Diameter of the drum (beater type)	..	..	..	..	..	17"
Length of the drum & mount on a	..	..	..	..	..	24"
Speed	..	..	..	..	..	1½" dia. shaft
No. of oscillation of the shakers	..	..	..	..	..	1400 R.P.M.
Distance of throw	..	..	..	..	..	200 per minute
Nos. of shakers	..	..	..	..	..	6"
	..	..	..	..	..	4

Both of them have what is known as bagging attachment through an elevator and the threshed grain is cleaned, graded and bagged and the larger machine is fitted with a chaff blower which will deposit chaff wherever desired within a radius of approximately 12 ft. The machines were operated in the farm during the months of April, May, June, 1949 in crops of wheat, oats, peas and burseem. The operation of the machines was found very satisfactory, but repairs and breakdowns were frequent due to the poor quality of timber used and some weaknesses in structural design. The output of the machines and the power unit used are as follows :—

Dania Threshing Machine No. 1.

Crop	Average output per hour		Machine run with.
Barley	..	5 mds. 1 seer ..	..
Oat	..	3 mds. 9 seers	..
Wheat	..	2 mds. 36 seers.	.. Mobile Diesel Unit 5-7HP

Dania Threshing Machine No. 2.

Crop	Average output per hour		Machine run with.
Peas	..	8 mds. 27 seers	..
Wheat	..	3 mds 20 seers	.. A Fordson Major Tractor of 20-26 H.P.

A cost data of these threshers compared to other methods of threshing is under preparation. The importing firm in Madras, have stated that they will shortly start production of these machines with certain minor modifications.

Trials of the Combined Harvester Thresher.—In the great plains of Canada and U.S.A. and in parts of England and Australia, small grains as wheat and barley are harvested by machines known as combines, which in one operation cut the standing Crop, and separate the grain, chaff, straw and dust and bag the clean and graded grain. During the recent war self-propelled machines were built and used in the U.S.A., which cut down labour costs to a minimum and involved no time or grain losses in opening up fields.

A few self-propelled combines have recently been imported to India and some of them are in operation in the United Provinces. A self-propelled combine manufactured by the Massey Harris Company of Canada was purchased by the Institute recently. It was tried out in the I.A.R.I. farm

on wheat and barley, both as a stationary unit and also as a field machine. Generally the machine, which is complicated in the extreme is not—in its present design suitable for operation under conditions in India as they exist today. The following is a brief resume of results obtained during tests to date.

Platform lift mechanism.—In India, the lifting and lowering of the platform is necessary every few yards in order to escape the fouling of irrigation bunds and not as probably is the case in countries of the West, every few hours, and under these conditions design of the operating mechanism must be modified. At present the lift mechanism is electrically controlled but it is thought that the inclusion of a manually operated lifting and lowering device is essential as, in the event of a breakdown in the existing Electrical mechanism the machine is rendered completely inoperative under irrigated conditions.

Reel or Sweep.—In India, where straw is nearly as valuable as the grain itself, it is imperative that stubbles left are practically nil. In the cutting of the full straw it was found that the existing adjustment would not allow the sweep to be lifted sufficiently high to operate effectively and this combined with the facts that the straw and grain here are very dry and brittle under harvesting conditions resulted in considerable quantities of grain heads being broken off. Certain modifications have been adopted to raise the sweep beyond existing allowable limits and a sweep fitted with 4 blades instead of 6 have both proved more effective than at present.

Straw Collection.—To make the combine acceptable under Indian conditions, it is necessary to have, some simple arrangement to collect the straw and dump it at intervals so that its removal from the field is made easier and economical.

Starting.—The engine of the combine is entirely dependent on an electric self starter for starting purposes. In the event of the failure of battery the engine cannot be handcranked unless one of the main road wheels is removed. A modification in design to make the engine more easily accessible for cranking and repair when necessary is essential.

Towing.—Provision of towing hook is also essential and should be provided in case of engine failure in the field.

Fertiliser Placement Machine.—Field crops and vegetables which are planted in rows can also be fertilised by placement of the chemical fertiliser in bands on either side of the seed in most optimum quantities to produce economical crop yields. The quantity of placement of fertiliser and its particular location with reference to the seed by machine placement is the subject of experiment in foreign countries. A fertiliser placement machine was obtained from the U.S.A. and further modified so that fertiliser in two bands on either side of the seed could be placed within the limits of plus or minus $1\frac{1}{2}$ lbs. per acre and at varying distances and depths relative to seeds.

The ultimate objective of these experiments is to evolve a simpler fertiliser placement machine within the resources of the cultivator or village co-operative interests.

PROGRAMME OF WORK FOR 1949-50.

1. Design, development and testing of ploughs suited to the draft, capacity of bullocks.
 - (a) Continuation of work on the twin country plough.
 - (b) Design of a suitable hitch for single animal hitched to a single bottom country plough.
2. Relative costs of tractor operation by different fuels such as diesel, kerosene, petrol and alcohol.
3. Modifications and trial of the combined harvester thresher.
4. Modification in the design of threshing machines, obtained from abroad.
5. The use of super disc ploughs for land reclamation work—performance and costs.
6. Determination of the suitability of agricultural implements for Indian agriculture, which are under import from Japan.
7. Development of a bullock gear or sweep power for operation of stationary machines by using bullock power.
8. A study of labour requirements in crop production.
9. Design, development and testing of harvesting machines suited to—
 - (1) Hand Power,
 - (2) Bullock Power and
 - (3) Engine operated.

APPENDIX I.

1. Director—Dr. J. N. Mukherjee, C.B.E., F.N.I., F.R.S.B., F.C.S.
2. Assistant Director and Head of the Division of Botany—Dr. B. P. Pal, M.Sc., Ph.D. (Cantab), F.L.S.
3. Registrar—Shri N. C. Pal, M.A., B.L.
4. Personal Assistant to the Director—Shri J. M. Banerjee, M.A.

Botany Division.

1. Head of the Division—Dr. B. P. Pal (Please also see item 2 above).
2. Geneticist—Dr. N. Parthasarathy, B.A., B.Sc. (Agr.), Ph.D., F.N.I.
3. Plant Physiologist—Dr. R. D. Asana, M.Sc., Ph.D. (Lond.), D.I.C.
4. Cytogeneticist—Dr. P. N. Bhaduri, Ph.D.
5. Systematic Botanist—Dr. D. Chatterjee, M.Sc., Ph.D. (Lond.), from 11-6-1949.
6. Assistant Geneticist—Shri R. B. Deshpande, M.Sc. (Agr.), Assoc. I.A.R.I.
7. Assistant Plant Physiologist—Shri T. J. Malkhani, M.Sc.
8. Assistant Cytogeneticist—Shri M. J. Deshmukh, M.Sc., Assoc. I.A.R.I. from 11-1-49.
9. Assistant Geneticist—Dr. F. H. Abbasi, B.Sc., Ph.D. from 1-5-49.
10. Assistant Botanist—Shri Harbhajan Singh, M.Sc., Assoc. I.A.R.I. (Plant Introduction Scheme).
11. Assistant Economic Botanist (Maize Scheme)—Dr. F. H. Abbasi, B.Sc., Ph.D., from 16-7-48 to 30-4-49.

Chemistry Division.

1. Head of the Division—(Dr. J. N. Mukherjee, Director held charge).
2. Soil Survey Officer—Dr. R. V. Tamhane, M.Sc., Ph.D. (Lond.).
3. Biochemist—Dr. N. B. Das, Ph.D. from 18-9-48.
4. Organic Chemist—Dr. K. C. Gulti, Ph.D. from 4-10-48
5. Soil Microbiologist—Dr. S. V. Desai, B.Sc., Ph.D., D.Sc., D.I.E. (on leave).
6. Physical Chemist—Dr. B. Chatterjee, D.Sc. from 14-1-49.
7. Assistant Agricultural Chemist—Shri M. A. Idnani, B.Sc. (Hons.), Assoc. I.A.R.I.
8. Assistant Soil Microbiologist—Dr. N. D. Vyas, M.Sc., Ph.D.
9. Assistant Physical Chemist—Dr. B. B. Roy, M.Sc., Ph.D., A.R.I.C. (Lond.).
10. Assistant Soil Survey Officer—Dr. K. V. S. Satyanarayana, B.Sc. (Agri.), Ph.D., Assoc. I.A.R.I.
11. Assistant Soil Survey Officer—Shri L. M. Mathur (Offg.), M.A.B.T., A.S.T.
12. Assistant Soil Chemist—Dr. W. V. B. Sundara Rao, M.Sc., Ph.D., Assoc. I.A.R.I. (on other duty).
13. Assistant Organic Chemist—Dr. A. C. Bose, B.Sc. (Hons.), Ph.D., A.I.C. (Lond.) from 29-11-48.
14. Assistant Organic Chemist (temporary)—Dr. H. D. Bhowmik from 30-4-49 afternoon.
15. Experimental Physicist—Dr. C. Dakshinmurthi, M.Sc., Ph.D.

Mycology Division.

1. Head of the Division—Dr. R. S. Vasudeva (Offg.), D.Sc. (Lond.), Ph.D. (Lond.), D.I.C.
2. Assistant Plant Pathologist—Dr. R. Prasada, M.Sc., D.Sc. (Agra).
3. Assistant Plant Pathologist—Dr. M. L. Gattani.
4. Assistant Virologist—Dr. S. P. Roy Chaudhuri, M.Sc., Assoc. I.A.R.I.
5. Assistant Systematic Mycologist—Dr. M. K. Hingorani, B.Sc. (Agri.), Ph.D., Assoc. I.A.R.I. upto 25-3-49.
6. Assistant Plant Bacteriologist—Dr. B. L. Chona, B.Sc., Ph.D. (Lond.) from 26-3-49.

Entomology Division.

1. Head of the Division—Dr. E. S. Narayanan (Offg.), M.A., Ph.D. (Lond.), D.I.C.
2. Systematic Entomologist—Dr. S. Mukherjee, M.Sc., D.Sc.
3. Insect Ecologist—Dr. S. Pradhan, M.Sc., Ph.D. from 19-11-48.
4. Toxicologist—Dr. S. Pradhan, M.Sc., Ph.D. upto 18-11-48.
5. Assistant Systematic Entomologist—Shri B. B. Bose, B.Sc.
6. Assistant Systematic Entomologist—
Shri C. K. Samuel upto 22-3-49.
Dr. A. S. Srivastava from 23-3-49 to 8-6-49.
Shri C. K. Samuel from 9-6-49.
7. Assistant Insect Epidemeologist—Dr. R. P. Chaudhury, M.Sc., Ph.D. (Lond.), from 15-11-48.
8. Assistant Insect Physiologist—Shri Rattan Lal, M.Sc., Assoc. I.A.R.I. (Offg.).
9. Assistant Sugarcane Entomologist (B.C.R. Scheme)—Shri T. V. Venkatraman. M.Sc.

Division of Agronomy.

1. Head of the Division—Dr. T. J. Mirchandani, M.Sc., Ph.D.
2. Agronomist—Dr. P. C. Raheja, M.Sc., Ph.D.
3. Agronomist—
Shri S. Sen, M.Sc. upto 28-2-49.
Shri J. J. Chandnani, M.Sc. (Agri.) from 9-4-49 (Afternoon).
4. Agronomy—Dr. N. P. Datta, M.Sc., D.Sc. from 14-1-49.
5. Assistant Agronomist—Shri R. D. Verma, B.Sc., B.Sc. (Ed.).
6. Assistant Agronomist—Shri J. J. Chandnani, M.Sc. (Agri.) from 10-8-48 to 9-4-49.
7. Assistant Agronomist—Shri S. L. Relwani from 8-2-49.
8. Assistant Agrostologist—Shri P. M. Dabadghao, M.Sc.
9. Cattle Superintendent—Shri N. P. Fernandez, G.B.V.C.

Agricultural Engineering Division.

1. Head of the Division—Major D. T. Brown, A.M.I., Mech. E., M.I.B.A.E.
2. Agricultural Engineer (Temporary)—Shri R. Venkataramiah from 13-9-48.
3. Assistant Engineer—Shri A. K. Kaul, L.E.E.
4. Assistant Engineer—Shri K. S. Chopra.
5. Assistant Engineer—Shri A. D. Chugani upto 18-1-49.

Statistics Division.

1. Assistant Statistician—Shri M. V. N. Rao upto 6-9-48.
Dr P. V. Krishna Iyer, M.A., Ph.D. from 7-9-48 to 22-1-49.
Shri P. N. Saxena, M.A. from 17-1-49.

Sugarcane Breeding Station, Coimbatore.

1. Sugarcane Expert—Shri N. L. Dutt, M.Sc.
2. Second Cane Breeding Officer—Vacant.
3. Plant Physiologist (Sugarcane Physiology Scheme)—Miss R. Shah from 10-3-49.
4. Assistant Botanist (Spontaneum Expedition Scheme)—Shri S. K. Mukherjee, M.Sc.
5. Chemist (Spontaneum Expedition Scheme)—Shri K. V. Gopal Ayyar.

Agricultural Substation, Karnal.

1. Agronomist—Shri S. Sen, M.Sc. from 1-3-49.
2. Assistant Agronomist—Shri A. R. Khan, M.Sc., D.Sc.
3. Assistant Agronomist—Shri B. D. Ganguli, B.Sc. (Agri.).

4. Assistant Agronomist—Shri Y. C. Gupta, B.A
5. Cattle Superintendent—Shri U. P. Shaha upto 10-4-49.
Shri J. D. Sampath Kumaran, D.B.V.C., Ph.D. from 11-4-49.

Botanical Substation, Pusa.

1. Superintendent—Shri M. D. Nandkeolyar, M.Sc.

Potato and Wheat Breeding Substation, Simla.

1. Potato Breeding and Research Officer—Dr. Pushkar Nath, M.Sc., D.Sc. upto 19-6-49.
2. Assistant Geneticist—Shri S. D. Srinivasachar, M.Sc., Assoc. I.A.R.I. upto 19-6-49 when the substation was transferred under the Director, Central Potato Research Institute.

APPENDIX II.

TRAINING OF STUDENTS AND RESEARCH WORKERS DURING 1948-49.

(a) List of Students Awarded the Postgraduate Diplomas :—

Division of Botany.

<i>Name of Students.</i>	<i>Subject of thesis.</i>
Vishnu Swarup	Classification of varieties of <i>Hibiscus esculentus</i> and related species reference to their usefulness for plant breeding.
David Veluppi'lai Ariyanayagan	The relation of the rate of uptake of nutrients to different growth stages of wheat.
Nihar Ranjan Panigrahi	Study of seed germination in potato and the comparison of sproutlings and tuber methods of propagation.
D. Daniel Sundaraj	Cytological studies on the Tetraploids of <i>Eruca Sativa</i> Sarathy.
Krishnamurti Ramnathan	Investigations on the sterility of inter-specific crosses in <i>Linum</i> .
Bhupendra Nath Trivedi	On pith in sugarcane and sugarcane seedlings.
Khemraj Laljee Nakhtera	(a) The influence of the sowing date on the differentiation and development of the inflorescence in an early and a late variety of wheat. (b) The influence of soil drought on the growth and yield of 10 varieties of wheat pertaining to different classes of maturity.

Division of Agronomy.

Ishwari Prasad	Effect of spacing, size of tubers and potash on the yield of potato.
Badrinarayan Kanungo	Manurial experiments with Garden pea N.P. 29.
Gobind Paradas Das	Effect of spacing, depth of sowing and date of sowing on gram wilt.
Lawrence Jones David	Effect of placed and broadcast fertilizers on berseem.
Asharfi Ram	Study of mixed cropping with and without fertilizers.
Ram Teckchand Gandhi	Effect of organic nitrogen in the form of oil cakes and green manures on the yield of wheat Pb. C. 519.
Channu Dhar Dubey	Effect of N, P, K, and 6a at different levels and various combination on wheat Pb. C. 518.
Hercharan Singh	Effect of heavy doses of complete fertilisers with and without legumes in the rotation for building up soil fertility.
Batuk Nath Mathur	Study of the after effects of phosphate manuring of cowpeas on wheat Pb. C. 288.
Chandu Lal Rathi	Study of the after effects of phosphate manuring of berseem on wheat Pb. C. 518.
Sita Ram Obhori	Phosphate manuring of berseem with and without basal manuring with farmyard manure and green manure.

Division of Chemistry.

<i>Name of Students.</i>	<i>Subject of thesis.</i>
Pandurang Mahadev Joshi	Distribution of total and available phosphoric acid in the profile in the phosphate treated Berseem plots of I.A.R.I. Farm.
Shambhu Nath Kaul	Physico-Chemical study of profile of black cotton soil.
Mysore Ramarao Chandrasekhara	Studies on the culture of major mineral nutrient in the leaf of the crop grown in the permanent manurial experiments at Pusa.
Sunil Kanti De	The effect of minor element on nitrogen fixation by gram roots nodule.

Division of Entomology.

Manohar Lal Prohat	(a) Relation of metabolic activities of the insect pests of stored grain to their susceptibility to some fumigants. (b) A review of work done on the fumigation of the insect pests of stored grains in the world.
Shewaram Choritram Bhatia	(a) Relation of specific susceptibility to amounts of HCN recovered after fumigation from different species of insect. (b) A review of work done on the significance host-selection in biological control.
Hukam Singh	(a) Chaetotaxial studies of immature stages of <i>Plusia</i> spp. (b) A review of chaetotaxial work on <i>Lepidoptera</i> of the world.
A. Vedamoorthy	(a) Behaviour of the house fly (<i>Musca sp.</i>) towards light. (b) A review of the ecological work done on <i>Musca spp.</i> in the world.
Gokul Chandra Sen Gupta	(a) Factors governing the host-selection of <i>Bracon Gelechiæ</i> , a parasite of the potato tuber. (b) A review of work done on the significance host-selection in biological control.

Division of Mycology.

Taresh Charan Roy	Studies on the soil microorganisms with special reference to antagonistic action against <i>Pasurium udum</i> Butl., the wilt organism of Ahar.
Jagnnath Singh	1. Study of the Bottle-gourd mosaic Virus. 2. Knol Knol Mosaic Virus.
Homi Priojsha Chothia	Studies in Safflower rust <i>Puccinia Carthamii</i> (Hutz) Corda in India.

(b) Students admitted during the year :—

Agronomy.

- | | |
|-------------------|--------------------|
| 1. B. H. Tatil | 7. A. S. Rana |
| 2. J. R. Kakde | 8. A. K. Mukherjee |
| 3. M. S. Joshi | 9. B. P. Singh. |
| 4. L. B. Lanjewar | 10. D. K. Misra |
| 5. I. L. Malhotra | 11. N. Mukherjee |
| 6. K. C. Misra | 12. S. M. Tripathi |

13. Q. S. Dhaka
14. G. N. Misra
15. V. T. Motwani
16. G. S. Shankhla

17. S. R. Roy.
18. N. Wadhwa
19. H. Gurubasvaraj

Botany.

20. P. Sanyal
21. K. N. Singh Gahlot
22. K. K. Pandey
23. S. P. Mital
24. S. Ramanujam
25. R. N. Srivastava
26. P. K. Kaushal

27. P. S. Shrivastava
28. J. P. Shrivastava
29. D. G. Gupta
30. S. S. Venkata Rao
31. S. C. Singh Mann
32. N. A. V. Krishnamurthy
33. S. C. Nag Biswas

Chemistry.

34. T. L. Deshpande
35. B. R. Gangwar
36. Babu Shyam
37. R. D. Tripathi

38. S. D. Sinha
39. A. S. Verma
40. A. Sankaran
41. B. B. Rudra

Entomology.

42. G. K. Nair
43. M. Shankar Rao
44. B. R. Subba Rao
45. H. J. Bhombhani

46. A. N. Chowdhury
47. M. G. Jotwani
48. Devi Singh

Mycology.

49. K. C. Shahare
50. K. G. Nema
51. Gopal Swarup
52. Harish Chandra Arya

53. K. L. Maheswari
54. D. S. Malla
55. C. Das
56. M. H. Rao

(c) Students admitted for short courses of training :—

Name.	Division.	Period.
1. Prem Datta Sharma	Agrl. Engg.	8½ months
2. Uttam Singh	Agrl. Engg.	4½ months
3. Kala Prasad Mathur	Agrl. Engg.	3 months
4. B. D. Tiagi	Mycology	2 months
5. Amarnath Parashar	Mycology	2 months
6. Sant Singh	Chemistry	One year
7. N. Subramoney	Chemistry	One year

(d) Honorary Research Workers :—

Name.	Subject.
1. K. V. George	Active and inactive strains of <i>Colletotrichum falcatum</i> .
2. M. Ramanath Menon	<i>Alternaria</i> disease of onions.
3. H. J. Bhombani	Study of Insect Pests in Delhi.
4. S. R. Chitrapu	Plant Hormones.

(e) Research Fellows :—

1. Jagdish Singh	In Botany Division
2. G. N. Sharma	In Entomology Division
3. O. K. Sexena	In Mycology Division

APPENDIX III.

List of papers published during 1948-49.

- Abbasi, F. H. (1949) Effect of combination of mature plant characters and Physiologic resistance to stem rust on yield of wheat varieties. Indian Breed., J. Genet. and Plt. Breed., 6 : 11-18.
- Asana, R. S. & Mani, V. S. (1948) On some Physiological properties of extracts of wheat grains. Cur. Sci. 17 : 360-62.
- Asana, R. D. & Mani, V. S. (1949) Photosynthesis in the ears of five varieties of wheat. Nature 163 : 450-51.
- Brown, D. T. (1949) A new plough for Indian Cultivators. Cur. Sci. 18-5-49.
- Biswas, S. C., Singh, H. D. and Joshi, N. V. Comparative studies of Indian Soils, No. VIII : The comparative nitrifying capacity of soils. Ind. Jr. Agricul. Sci. Vol. XVI, Oct., 48.
- Das, S. C. & Motiramani, D. P. Preliminary studies on the Diseases of Gram. Cur. Sci. Feb., 1949.
- Dutt, N. L. & Rao, J. T. (1949) Pistillody in Saccharum. Cur. Sci. Aug., 43, 17, 241-242.
- Dutt, N. L., Rao, J. T. & Davis, T. A. Uniform Glazed pans for raising Sugarcane Seedlings. Cur. Sci. Sept. 48, 270-271.
- Dutt, N. L. & Rao, K. S. S. (1949) On the so called deterioration in Sugarcane Varieties. Proc. Ind. Sci. Cong. 1949.
- Deshmukh, M. J. (1948) The use of potato chips, eyes and sprouts as seed. Sci. & Cult. 14 : 460-62.
- Deshpande, R. B. (1949) A case of simultaneous mutations of two independent genes in the chilli, *capsicum annuum* L. Cur. Sci. 18 : 171-72.
- Garga, R. P. (1949) *Schizanthus* sp. a host of tobacco leaf curl virus. Cur. Sci. 18 : 260-261.
- Gattani, M. L. & T. N. Kaul (1949) Studies on Panicillin producing strains of *penicillium notatum chrysogenum* series in India. Proc. 36th Session Ind. Sci. Cong. Assoc., Allahabad Pt. III. Sec. of Agricul. Sci. 201-202.
- Gupta, Y. C. (1948) Cost of making silage. Ind. Farming. 9 : 70-72.
- Idnani, M. A. (1949) Use of Sulphate of Ammonia as Fertilizers with special reference to Sind. Ind. Farming, Vol. X, Jan., 1949.
- Joshi, N. V. & Biswas, S. C. (1949) Does Photo-nitrification occur in the Soil. Ind. Jr. Agricul. Sci. Vol. XVIII, Sept., 48.
- Mukherjee, S. & Venkatraman T. V. (1948) Studies on *Epipyrops malanoleuca* Fletcher". (Lepidoptera, Epipyropidae) an ectoparasite of the Sugarcane leaf hopper, *Pyrilla* Spp. (Homoptera, Fulgoridae). Proc. Zool. Soc., Bengal, Vol. 1, pp. 97-102.
- Mukherji, S. & Chatterjee, S. N. (1949) "*Diacretus aphidae* sp. nov. parasitic on *Pterochlorus persicae* chodk, affecting *Prunus persicae*, (Peach) in Baluchistan." Proc. 36th Session, Ind. Sci. Cong. Assoc., Allahabad. pp. 193.
- Narshimhan, R. & Dutt, N. L. (1949) Effect of H-iron concentration and salt of the madium in the development of salt roots in Sugarcane. Proc. Ind. Sci. Cong., 1949.

- Narayanan, E. S. Venkataraman, T. V. & Sen Gupta, G. C. (1948) Studies in Exptl. Insect Parasitism—Superparatism. *Cur. Sci.* Vol. 17, pp. 269-370.
- Pal, B. P. (1948) Control of wheat rust by breeding. *Jr. Ind. Bot. Soc.* 27 : 169-185.
- Pal, B. P. (1948) Some aspects of wheat improvement in India. *Indian J. Genet. & Pl. Breeding* 8 : 59-67.
- Pal, B. P. & Ramanujam, S. (1949) Recent advances in the technique of plant breeding and seed multiplication and the Scope for increasing the yield and production of crops under Indian conditions. *Ind. J. Genet. and Plt. Breed.* 6 : 48-60.
- Pal, B. P. & Hasanain, S. Z. (1946) (paper appeared in 1948-49). A study of the selection of certain morphological and functional characters to the stem rust resistance of wheat varieties. *Ind. Jr. Agricul. Sci.* 16 : 459-60.
- Pal, B. P. (1949) Tackling the food problem. *Ind. Farming* 10 : 149-51.
- Pradhan, S. (1949) Studies on the Toxicity of Insecticides "Films". I. Preliminary investigations on concentration-time mortality relation. *Bull. Ent. Res.* London. 40 : 1-25.
- Prasada, R. & Verma, U. N. (1948) Studies on Lentil rust, *Uromyces fabae* (Pers). de Bary in India. *Ind. Phytopathology*, 1, 2 : 142-146.
- Pushkar Nath (1948) Increasing potato production. *Ind. Farming* 9 : 289-93.
- Raheja, P. C. & Das, G. P. Analysis of Agricul. yields II. Effect of cultural treatments on the incidence of gram wilt (*F. Orthocaea Caerii*) *Ind. Sci. Congr. Assoc.* Allahabad, 1949.
- Raheja, P. C. Selection varieties in relation to ecological Habitat. *Ind. Sci. Cong. Assoc.*, Allahabad, 1949.
- Raheja, P. C. Supplemental Fodders & Feeds for Dairy Stock. A.H.W. Meeting of the Bd. Agr. & A. Hus. in India, Bangalore, 49.
- Raychoudhury, S. P. & Ramamurty, B. (1949). The ultraviolet absorption spectra of mosaic viruses of sunhemp & cow pea. *Proc. 36th Session Ind. Sci. Cong. Assoc.*, Allahabad, 49. Pt. IV. Section of Agricul. Sciences.
- Samuel, C. K. (1949) The correlation between the heights of tobacco plants and the type of leaf curl infesting them with field. *Proc. 36th Session Ind. Sci. Cong. Assoc.*, Allahabad, 49.
- Singh, H. B. & Pal, B. P. (1948) How to make India self sufficient in food production. *Rur. India*, 12 : 137-139, 1949.
- Singh, H. B. & Pal, B. P. (1948) Utilization of wild relatives of tomato for breeding. *Sci. and Cult.*, 14 : 103-106.
- Singh, H. B. & Pal, B. P. (1949) Some observations on the interspecific cross *Luffa acutangula* Roxl. X *L. Cylindrica* (Lour) Roem (*L. aegyptiaca* Mill). *Proc. 36th Ind. Sci. Congr. Session*, Allahabad, 49. P. 196.
- Singh, H. B. (1948) Floral abnormalities in the egg plant *Solanum melongena* L. *J. Ind. Bot. Soc.* 27 : 21-25.
- Vasudeva, R. S. (1949) Soil borne plant diseases and their control. Presidential address. *Proc. 36th Session. Ind. Sc. Cong. Assoc.*, Allahabad, 1949, Pt. II, 173-186 Sec. of Agri. Sciences.

